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NOTICE TO READERS: Given the course of events in the former Soviet Union, FBIS will change the titles of Soviet publications to "Central Eurasia" on 6 January. The "USSR: Engineering & Equipment" report will be renamed "Central Eurasia: Engineering & Equipment."

Nuclear Energy

Non-Nuclear Energy

Turbines, Engines, Propulsion Systems

Mechanics of Gases, Liquids, Solids

Industrial Technology, Planning, Productivity

Subsurface Disposal of Highly Toxic Wastes. Simplest Geological- Hydrorheological Models

927F0001A Minsk DOKLADY AKADEMII NAUK BSSR in Russian No 3, Mar 91 pp 266-269

[Article by A.V. Kudelskiy, Institute of Geochemistry and Geophysics, BSSR Academy of Sciences]

UDC 550.36:551.49:624.131

[Abstract] The problem of subsurface disposal of highly toxic waste is analyzed by considering not so deep, medium deep, and very deep sites in various underground environments. Not so deep sites, up to 500 m below the surface, need to be located within either the aeration zone or the zone of active water exchange. Most favorable medium deep sites, 500-2000 m below the surface, are those within a megablock of crystalline rock or within fissures in sedimentary basin formations where artificial inclusions such as dumped toxic waste will be subject to upward mass transfer toward the zone of active water exchange by molecular diffusion only and heat transfer by conduction will maintain the temperature within the 50-70°C range. Very deep sites, more than 2000 m below the surface, can be found within fissures in crystalline rock in accordance with the Synrock project (T. Ringwood, NEW SCIENCE No 1229, 1980) and within sedimentary basin formations with mass transfer along the interface between the crystalline bed or regionally exposed salt layers and the zone of active water exchange by predominantly by molecular diffusion. The territory of the Belorussian SSR can, on the basis of this classification, be divided into regions geologically and hydrogeologically suitable for disposal of toxic industrial and municipal waste. Figures 2; references 4.

Is There a Nuclear Monster Near the Kola Peninsula?

927F0026A Moscow RABOCHAYA TRIBUNA in Russian 9 Nov 91 p 2

[Article by Sergey Doronin, Military Reviewer of RABOCHAYA TRIBUNA: "Is There a Nuclear Monster Near the Kola Peninsula?"]

[Text] Approximately 60 units of various types of nuclear weapons, 12 reactors—Soviet and American—rest on the ocean bottom. This is according to the journal NEPTUNE PAPERS. Man has sunk approximately 168-240 kg of plutonium warheads and 1,120-1,240 kg of nuclear materials. This includes nuclear fuel as well. What will then be the payoff for the desire of the leading countries of the planet to become "equal" with respect to weapons? The combat fleets are now equipped with more than 550 reactors and 14,000 nuclear warheads.

A phantom wanders about the Kola lands. This is a phantom of a nuclear monster. Until recently the staid reasonable northerners half turn when they hear the word "atom," and try not to understand. Six nuclear icebreakers are all "tied" to Murmansk. This includes more than 100 nuclear submarines equipped with nuclear missiles and torpedoes, and two nuclear cruisers. There is a total of 238 nuclear transport reactors. Add to this the stationary reactors at the Kola AES. Is there any other region in the Soviet Union that is not so saturated with nuclear power engineering? Don't look, you won't find one. And how can one not wonder without shuddering: which barrel are you sitting on and what is in it?

The event on the nuclear icebreaker "Rossiya" in November 1988 is also remembered here. At that time, there was almost a meltdown of the nuclear fuel in the operating reactor. It was possible to correct the error of the specialists. But the nuclear-hazardous situation continued for almost 4 minutes. And nowhere else but almost in the center of Murmansk!

But one must not forget: the scale of the accidents in the nuclear fleet (and including the military fleet) over 30 years of existence are single. They are extreme. There is another daily circumstance, related to operation of transport ship power plants.

There is also the past, remembered by accidents and catastrophes. The losses due to them are measured not only by the number of human victims, but by material costs as well.

A resident of the "Kola Peninsula" looks at this problem in his own way. It is important for him to know what is happening nearby or what happened at some time. The question of one's safety disturbs everyone. And unseen rumors and fears arise. For example, shoals of mutant capelin wander here and there around the Kola Gulf.

I am interested in the Murmansk people's deputy of the USSR A. Zolotkov:

"Is it really true, Andrey Alekseyevich, that such fish have been found?"

"This is the first I have heard of it."

It is worth listening to Zolotkov's opinion. If anyone should know, he is one of those who is clear about the details of the concept "radiation hazard."

Everything had to be established as to how much, where and what we dumped overboard and buried in containers. Zolotkov performed this work alone for Murmansk Oblast. The deputy is convinced that the attitude toward the Kola region must be fundamentally changed. Otherwise he would be inevitably be ill in bed. Time still waits, but there is not much left.

The chief of engineering management of the Northern Fleet Rear Admiral Ye. Rogachev talks about the work of the oblast deputy committee in October of this year:

"The radiation cleanliness at the facilities was especially amazing. The radiation background in the messroom of the nuclear submarine was 6 microrems per hour. It was a unit greater on the nuclear missile cruiser "Kirov" with

an operating reactor. The deputies were also convinced of the order of temporary storage of solid wastes and of the reliability of various types of monitoring at shore facilities."

Does this mean that we are still controlling the nuclear monster? Or we should say are we controlling it for the time being?

We enthusiastically constructed the nuclear fleet—civil and military— and perfected it. Without thinking, or rather not giving much thought to the fact that during operation and maintenance of transport reactors and repair of them that wastes would inevitably appear, and that the vessels which had served out their life if not sent for reprocessing, then at least sent to the dump.

And don't try to bring an accounting to those who yesterday designed and assigned strategic directions to shipbuilding. They will reject any accusations toward them: "No one posed such questions to us." Whether true or not, these questions were not posed to them. And facilities for utilization were not allocated and are not being allocated. This is how they are extricating themselves in the fleets, how they are able to do so in their desire to protect the environment against nuclear carriers that have been written off.

I do not know whether there is a larger problem in Soviet nuclear power engineering than that of reprocessing and prolonged storage of radioactive wastes. And there is even no overall accounting of such a seemingly elementary problem. Try to count how many of them have been accumulated in the country—a ton, 2 tons, 10 tons? You will not be able to find this, because you will have to "comb" through tens of departments. But even they can not name precise figures.

But, one should know something about all the burial sites. Otherwise sections with increased radiation background will be found from time to time in the cities.

This aspect of nuclear power engineering only alarms ecologists for the time being. And perhaps only operators to the greatest extent. And only because they have been left alone with the problem of storage and burial of wastes. And this is no exaggeration. Take the Northern Fleet for example. And there is no place to add to the nuclear compartments of the four nuclear submarines, written off and prepared for utilization. There is no regional burial site. And no one has any idea of how to proceed with the written-off nuclear carriers. More than two-thirds of these naval vessels are left at their deployment bases with unloaded cores. There are commanders on them, there are crews of several tens of persons, but they do not go to sea. We will have many tens of these nonsailing nuclear carriers by the end of the century.

Worldwide practice shows that this question should be one of the government rather than departments as it is in the USSR. It is true that neither the government of the so-called "center" nor the government of the sovereign states have as yet asked the question: Do we have some program or system of handling radioactive wastes, where to store them, how to reprocess them, from which budget to finance it, and whether anyone is capable of performing this work?

The time will come and we will suddenly remember, only if it is not too late.

Results of the Operation of TES Units in the Period From 1986 to 1990

927F0022B Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 91 pp 7-9

[Article by Yu.Yu. Shtromberg and I.A. Terentyev, All-Union State Trust for the Organization and Rationalization of Rayon Electric Power Plants and Systems]

UDC 621.311.22

[Abstract] During the past five-year-plan, the installed capacity of units at TES controlled by the USSR Minenergo has increased by 10%. The average per-unit installed capacity has increased from 258 MW to 263.3 MW. The park of 800-MW units has increased by 43% (from 14 to 20 units), and the parks of 250- to 300-MW and 180- to 210-MW units have increased by 7 and 10%, respectively. As of 1990, 353 units had been in operation for more than 100,000 hours, 202 had operated for more than 150,000 hours, and 31 had operated for more than 200,000 hours. The 1,200-MW unit at the Kostroma State Regional Electric Power Station [GRES] had the best operating indicators for 1990 (no failures and a utilization factor of 90.9%). The 500-MW units operating at TES had worse operating indicators than all other TES units. The operating indicators of the units of the Ekibastuz GRES-1 were worst of all: The units only operated between 231 and 251 hours, and their underutilization of capacity due to failures was between 10.1 and 19.8%. Heating station units with a capacity of 250 MW generally had very high indicators throughout the entire period from 1986 to 1990. The two 250-MW units at the TETs-5 of the Kievenergo had the best indicators of all for 1990: utilization factor, 93.8%; duty factor, 93.2%; installed capacity utilization factor, 96.8%; average load, 235 MW; operating time to failure, 8,166 h; and underutilization of capacity due to failures, 0.1%. The operating indictors of 800-MW units declined somewhat in the past five-year-plan, but they still remain above the indicators of domestic 500-MW units and are no worse than the operating indicators of foreign units with capacities of 600 MW or more. The indicators of other groups of units with other capacities (150 to 165, 180 to 210, and 300 MW) also dropped somewhat during the period in question but have also remained at least on a par with analogous units in the United States and Western countries. The following units have operated virtually without failures: six 150-MW units at the Berezovo GRES and seven 150-MW units at the Irkutsk TETs-10; six 200-MW units at the Belovo GRES, six such units at the Dzhambul GRES, and four at the Pechora GRES; and eight 300-MW units at the Konakovo GRES, eight of the same at the Kostroma GRES, three at the Central Ural GRES, and six at the Tripolsk GRES. Total unit failures increased from 2,621 in 1986 to 3,103 in 1990 (i.e., by 18.4%). At the same time, installed capacity increased by only 10.2%. The causes of these failures were as follows: due to boilers or auxiliary boiler equipment, 40.6%; due to turbine and auxiliary turbine equipment, 20.6%; due to electrical equipment, 15.4%; and due to pipelines and fittings, 6.0%. The following plants had the worse indicators with respect to underutilization of capacity due to failures in 1990: the Troitsk GRES (two 500-MW units), 20.1%; the Ekibastuz GRES (eight 500-MW units), 19.8%; the Azerbaijan GRES (eight 300-MW units), 19.8%; and the Tbilisi GRES (eight 150-MW units), 16.7%. Tables 4.

Critical Problems in Planning the Retooling of TES

927F0022C Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 91 pp 42-45

[Article by V.P. Dulenin and V.V. Romantsov, engineers, Ural Department, All-Union Scientific Research and Design Institute of the Power Industry]

UDC 621.311.22.004.69

[Abstract] The experience gained to date in planning for the retooling and redesign of the country's TETs has made it evident that the document entitled Main Policies Regarding the Retooling and Redesign of the Thermal Electric Power Plants of the USSR Minenergo up to 1990 and Between 1991 and the Year 2000 [henceforth referred to as the Main Policies] is in need of significant revision. This need for revision is due mainly to the following: the extremely large scales of the work and expenditures required for the said retooling, the fact that there is no way possible for manufacturing plants to supply the equipment needed for the planned retooling, and the need to give further consideration to the evolving trends with respect to the relationship between ecology and fuel use in power engineering over the next 10 to 15 years. The estimated costs of retooling the 22 TETs and 15 GRES included in the system of the Ural Fuel and Power Department will amount to 1.1 and 2.5 billion rubles, respectively, for a total of 3.6 billion rubles that must be spent between 1990 and 2000. Analysis of data regarding the reliability and economic indicators of equipment at power generation facilities administered by the USSR Minenergo confirms that many of the assumptions underlying the main policies are incorrect. It is true that replacing old equipment with low operating parameters by new equipment with higher parameters is undoubtedly the best route to follow. In view of the limited available financial and physical resources, however, another approach must be adopted. More focus must be placed on lengthening the useful life of existing equipment wherever safety would not be sacrificed. Data obtained at the Sverdlovsk TETs-1 and the Sterlitamak TETs illustrate that following the retooling guidelines established in the Main Policies is not always best from a fuel economy standpoint and does not necessarily result in an improvement in reliability indicators. Neither should there be any universal policy of replacing all 3.0- and 10.0-MPa equipment that has outlived its useful life. The most sensible way to proceed is to compare the relative benefits that will be obtained in each individual case by (1) completely replacing all

old equipment by new equipment, (2) extending the life of the old equipment, or (3) replacing a portion of the old equipment and extending the life of the other portion. The formula currently used for the technical and economic comparison of retooling scenarios is based exclusively on costs. The experience gained in planning the supply of heat and power to Neftekamsk, a young and growing city located 30 km from the Karmana GRES, illustrates that the comparison of alternative versions of supplying heat and power to a given area must be based on the "rule of identity." In other words, the formula used to compare power generation scenarios must be revised to give consideration not only to costs but also to such difficult-to-measure factors as effect on the environment (including pollution levels and living conditions in the area), reliability, the ability to burn readily available types of fuel, and number of persons required to man the power generation facilities. Perhaps the most important problem in planing for retooling is that of predicting the useful life of different types of equipment. At present, reliable life is calculated solely on the basis of statistics, experience, and intuition. Scientific research institutes must begin immediate work to develop a method to predict reliable life and also to be able to consider the aforementioned difficult-to-measure factors so that alternative retooling plans can be compared on a truly equal footing. Table 1.

Estimating the Technical Condition of Hydrogenerators

927F0022D Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 91 pp 67-70

[Article by Yu.M. Elkind, doctor of technical sciences, All-Union Scientific Research Institute of Electric Power Generation]

UDC 621.313.322-82

[Abstract] Timely decision making regarding the further operation of generators after defects in their operation have been detected will increase the probability of preventing failures and accidents, reduce the time and costs of restoring the damaged equipment, and maintain the power system's standby capacity. The ability to make such decisions hinges on the possibility of making a quick estimate of a generator's technical condition with a sufficiently high degree of reliability. The most critical problems in increasing the reliability of quick estimates of generators' technical condition are as follows: providing systems for standard monitoring of hydrogenerators by means of priority diagnostic equipment, developing methods for quick forecasts of a generator's operating time to failure from the moment a defect has been discovered to the moment of failure, compiling recommendations regarding the collection and processing of information about generators' technical condition, and organizing an automated bank of information regarding generators' technical condition. Possible sources of such information include the readings of standard monitoring and diagnostic devices; the organoleptic perceptions of GES personnel; analysis of the results of examinations, tests, repairs, and updating; and analysis of peculiar operating modes and failures during past periods of operation. Existing standard generator diagnosis systems are not, however, capable of providing adequate information for timely detection of defects in generators' operation. Specifically, devices for the following are lacking: detecting the early stages of overheating of active steel, insulation, or contacts that do not have temperature sensors located close to them; monitoring the local overheating of the steel of poles, insulation, or the contacts of field windings, jumpers, and rotor conductors, etc.; monitoring the overheating of rotors' damper windings or their contacts; monitoring generators' vibrations and noise; and monitoring electromagnetic radiations and a number of other symptoms of defects in a generator's operating process. Existing standard generator-monitoring equipment only makes it possible to detect about 19% of all key defects (as opposed to 76% when modern diagnostic equipment is used). Studies have indicated that priority should be given to developing standard devices to monitor overheatings, electromagnetic radiations, pulse currents, and vibrations and noise made by generators. The All-Union Scientific Research Institute of Electric Power Generation [VNIIE] had developed a system to detect overheating. The system includes gas-releasing and color heat-indicating coatings, ionization chambers, a chromatograph, a recorder, and other auxiliary devices. Regions of overheating are detected on the basis of their characteristic gas, and sites of overheating are detected based on examinations of the color indicators. Production of the system has yet to begin, however. Methods to diagnose electromagnetic radiations following the impairment of contact connections, etc., have yet to be developed. The development of standard devices to monitor hydrogenerators' vibration and noise has not yet been completed. Perhaps most important is the fact that no method for quick diagnosis of a hydrogenerator's technical condition has been developed. Such a method must give consideration to the correlations between different key defects and the effect of those generator operating modes that can have a significant effect on the rate at which key defects develop. For the present, GES personnel should be instructed to shut down a generator immediately upon the detection of smoke, flame, water flows, electrical arc discharges, and failures of protective devices. Detection of elevated temperature and vibration levels should trigger immediate tests of the generator in a no-load mode and are grounds for performing regularly scheduled inspections, tests, and repairs ahead of schedule. Figure 1, tables 3; references 4 (Russian).

Calculating the Irradiation and Optimizing the Orientation of Solar Photoelectric Stations

927F0023A Ashkhabad IZVESTIYA AKADEMII NAUK TURNMENSKOY SSR: SERIYA FIZIKO-TEKHNICHESKIKH, KHIMICHESKIKH I GEOLOGICHESKIKH NAUK in Russian No 3, May-Jun 91 (manuscript received 28 Sep 90) pp 11-20

[Article by E.S. Abdylkhekimov, E.S. Avanesov, and V.M. Yevdokimov, Gelios Scientific Production Complex]

UDC 621:499

[Abstract] Eight possible methods of orienting the ray-receiving surface of solar photoelectric stations are introduced. Six of the orientations (designated s, δ, z, ψ, ξ, n) have been discussed elsewhere. Two others (designated τ and t) are proposed by the authors. The optimum tilt angles and annual totals of solar radiation received at these angles are calculated for five weather stations in Turkmenistan (i.e., the weather stations in Ashkhabad (located at 37°58' N Lat), Chardzhou (at 37°0.5' N Lat), Akmolla (located in the Tashauz Oblast at 39°35' N Lat), Bekibent (Krasnovodsk Oblast, 38°37' N Lat), and Gasan-Kuli (Krasnovodsk Oblast, 37°28' N Lat)). No clear correlation between geographic latitude and optimum slope is found. This is explained by the difference in climate (percentages of direct and scattered radiations) and natural (albedo, etc.) factors in each of the individual areas. What is termed the n orientation (i.e., the collector's surface completely tracks the visible motion of the sun) is found to be the most productive. The s orientation (i.e., the collector's surface is sloped at the optimum angle α_{opt} to the horizon and turned toward the equator) is found to be the least productive; it results in an energy loss of about 30%. The orientations δ (i.e., the collector surface is turned to the equator and follows the slope δ of the sun in the first equatorial coordinate system) and z (i.e., the collector surface follows along the zenith distance to the sun in a horizontal coordinate system, with the normal to it shifting in the plane of the meridian) orientations are recommended for use when operating solar photoelectric power stations with a capacity of more than 1 kW. This is because when they have a well-balanced design extended in an east-west line there is no need for a single-drive tracking mechanism with a corresponding power. The s orientation is deemed more suitable for this setup, however, because it has a high degree of reliability. Moreover, solar photoelectric power stations do not absolutely need to be drawn into a single line. Instead, they may be configured in the form of a compact field with the respective number of lines. This is very important from operation and maintenance standpoints. Low-power solar photoelectric stations (less than 1 kW) lend themselves to the use of the ψ (the collector surface is sloped at the optimum angle α_{opt} to the horizon and follows only along the sun's azimuth in a horizontal coordinate system) and ξ (the collector surface follows along the hourly angle of the sun in the first equatorial coordinate system and is sloped at the optimum angle β_{opt} to the horizon at that moment when the normal to it is turned to the equator) orientations. These two orientations have a high productivity (3-5% less than the n orientation) but are not without their individual drawbacks. In view of this fact, the authors propose what they term the τ and t orientations. The τ orientation is similar to the ψ orientation; however, instead of a nonuniform rotation when following along the sun's azimuth, the collector rotates uniformly as if following the law governing the change in ξ. The t orientation is similar to the ξ; the only difference is that the rotation axis lies in the plane of the collector area and the slope γ of the rotation axis to the horizon is optimized. Calculations of the correctness of selecting these two new orientations indicate that their productivity losses amount to not more than 2.3 and 0.3% respectively as compared with the ψ and ξ orientations while eliminating the shortcomings of the latter. The τ and t orientations are therefore recommended for practical development of solar photoelectric stations. The τ orientation is deemed preferable from the standpoint of soundness of design and specific consumption of materials. The adequacy of the mathematical models used is discussed. Figures 2, tables 4; references 10: 7 Russian, 3 Western.

Calculating Heat Engineering and Production Characteristics of a Biogas Unit That Uses Solar Energy

927F0023B Ashkhabad IZVESTIYA AKADEMII NAUK TURNMENSKOY SSR: SERIYA FIZIKO-TEKHNICHESKIKH, KHIMICHESKIKH I GEOLOGICHESKIKH NAUK in Russian No 3, May-Jun 91 (manuscript received 15 Sep 89) pp 53-56

[Article by K. Kelov, R. Bayramov, I.R. Yuferev, and A. Kashanov, Solntse Scientific Production Association, Turkmen SSR Academy of Sciences]

UDC 621.472:620.92

[Abstract] The authors calculate the heat engineering and production characteristics of a ground-type solar-powered biogas unit that was described in a previous publication. The calculations performed were based on the following conditions of the said biogas unit. The biogas unit (i.e., methane tank/fermenter) was covered with a heat-insulating material 0.07 m thick. A metal mesh was used to hold the insulation on the fermenter's surface, and the skeleton was filled with asbestos. The outer surface of the insulation was painted with a light water-resistant paint. The paint cracked, however, and moisture seeped through, changing the insulation's heat conduction in the process. Because of this, the empirically determined heat losses experienced by the ground fermenter were 25% greater than the design heat loss. A series of empirical tests enabled the authors to determine that this discrepancy is due to the fact that the formula used to calculate design heat losses does not give consideration to meteorological factors (including wind speed

and humidity) or to the possibility that the insulation used on a fermenter will consist of a combination of materials with very different thermal characteristics (in the case in question the insulating asbestos is in contact with a metal mesh). In the second phase of their research, the authors sought to remedy this heat loss problem by designing solar collectors with natural circulation to compensate for the heat losses incurred. They designed solar collectors that use ordinary tap water as coolant. Natural circulation forces the heated water to enter the fermeter's water sleeve. After cooling to the process temperature inside the fermenter the water returns to the collector, thus forming a closed cycle. Empirical formulas are presented for determining the collector area required to compensate for the fermenter's heat losses due to various factors and the volume of biogas traveling from the fermenter to the unit's gas holder. It is concluded that the amount of biogas (in dm^3) entering a gas holder of the biogas unit under consideration will amount to 10.487 times x, with x being the height to which the cap is lifted in cm. References 3 (Russian).

Scientific and Technical Base of Program for Reconstruction and Renovation of Thermal Electric Plants

927F0021E Moscow TEPLOENERGETIKA in Russian No 6, Jun 91 pp 38-42

[Article by G.I. Moseyev, candidate of technical sciences, All-Union Institute of Heat Engineering]

UDC 621.311.22

[Abstract] Renovation of thermal electric power plants, which were rapidly becoming obsolete in the late 1970's, was suspended in the wake of the unforeseen Chernobyl nuclear accident and because of a lack of new guidelines regarding the kind of power equipment to be used as replacement. A comprehensive survey of trends in the development of thermal electric power plants since 1970 having been subsequently made with projections to the year 2000, scientific and technical analyses of the data indicate four possible solutions to the problem of their renovation with safety assurance. Most promising are steam-and-gas plants with boiler-recuperator sets and condenser engines or power-and-heating plants with gas turbines. The second possibility is expansion of existing gas and oil burning plants that can be reconstructed either by addition of gas turbines and feeding the hot flue gases fed into the steam generator or simply by replacement of the steam turbines with gas turbines. The main difficulty here is fitting the gas turbines into the main power house. The third possibility being considered is conversion from burning coal dust to "ecologically cleaner" burning of granular coal in a circulating fluidized bed. This requires a change of boilers, if the existing ones can be dismantled. This possibility is pursued at a slow pace, owing to problems in the design of unconventional combustion processes. The fourth possibility is mandatory reconstruction or replacement of the entire thermal electric power plant into an environmentally safe one. Following an evaluation of these possibilities for economical as well as technical feasibility, a new program is being designed for completion of the renovation project. The necessary research is done jointly by the All-Union Institute of Heat Engineering, the All-Union State Trust for Organization and Rationalization of Regional Electric Power Plants and Networks, the Central Scientific Research Institute of Machine Construction Technology, and the Scientific-Industrial Association "Central Institute of Boilers and Turbines", with assistance from the Siberian Institute of Power Apparatus Design and Technology and from several equipment manufacturing plants. This program provides also for updating the control and automation system in 300 MW thermal electric power plants, with use of "Remikont" microprocessors and with equipment built by the Scientific-Industrial Association "Impuls" replacing the old IV-500 equipment. Tables 2; references 3.

Ecologically Clean Thermal Electric Power Plant Burning Kansk-Achinsk Coals

927F0021A Moscow TEPLOENERGETIKA in Russian No 6, Jun 91 pp 8-12

[Article by M.Ya. Protsaylo, doctor of technical sciences, M.S. Pronin, candidate of technical sciences, V.G. Meshcheryakov, candidate of technical sciences, G.A. Khochan, engineer, V.F. Dyachenko, engineer, V.M. Ivannikov, engineer, and V.V. Gordeyev, engineer, Siberian branch, All-Union Institute of Heat Engineering; All-Union Institute of Heat Engineering; All-Union State Planning and Design Institute of Thermal Electric Power Plants; RSFSR State Planning Institute of Electrical Equipment for Heat Engineering Installations; REU Krasnoyarsk Regional Administration of Power System Management; Podolskiy Machine-Building Factory imeni S. Ordzhonikidze (ZiO)]

UDC 621.311.22.502.001

[Abstract] An ecologically clean fuel burning process has been developed for thermal electric power plants burning Kansk-Achinsk coals, these coals being quite easily extractable from abundant deposits. The main gist of this process is low-temperature combustion in a tangential furnace chamber with a solid slag removal ensuring minimal formation of nitrogen and sulfur oxides. This has been achieved by uniform comminution of coal lumps into coal dust containing not more than 1.5% of the R_{1000} fraction, by use of burners designed for early kindling and complete combustion, by aerodynamic shaping of the flame for combustion to take place near the screens and prevention of their clogging by unburned dust, with the maximum temperature within the flame core not exceeding 1300°C and the thermal flux not exceeding 1250 MJ/m^2. All these features are included in the Ye-500 boiler built at the Barnaul boiler manufacturing plant and installed at the Krasnoyarsk

heat and electric power plant, most of them are included in the P-67 boiler built by the ZiO and installed at the Berezovo state regional electric power plant. Coal from the Kansk-Achinsk Basin contains only 0.2-0.4 % nitrogen and 0.4% sulfur. The amount of nitrogen oxides in the smoke is reduced from as much as 0.38 g/m^3 to 0.2 g/m^3 by preheating of the coal dust in an oxygen-deficient atmosphere prior to its combustion and subsequently lowering the excess air in the furnace from the regular 1.22 to 1.1 only. The moisture content in raw coal is reduced from typical 33% to 13.5% by passing 65% of hot flue gases through the heap. Ash is removed by bag or box filters, much smaller and less costly than electric ones. For an ecologically clean operation of such a power plant, incoming coal should be kept in closed storage rooms rather than in open yards. A cost analysis indicates that construction of a new power plant with this new technology will be more economical than modification of existing equipment. Figures 3; tables 3.

Ecologically Clean Electric Power Plants Burning Ekibastuz Coal

927F0021B Moscow TEPLOENERGETIKA in Russian No 6, Jun 91 pp 12-18

[Article by R.A. Petrosyan, candidate of technical sciences, A.N. Alekhnovich, candidate of technical sciences, I.N. Shmigol, candidate of technical sciences, I.A. Sotnikov, engineer, and Ye.A. Fedorchenko, engineer, All-Union Institute of Heat Engineering; Ural branch, All-Union Institute of Heat Engineering; Podolskiy Machine-Building Factory imeni S. Ordzhonikidze; Ekibastuz Regional Administration of Power System Management]

UDC (621.311.22:502).001

[Abstract] Ecologically clean operation of electric power plants burning Ekibastuz coal is problematic, inasmuch as this coal has a high ash content along with a large amount of bound nitrogen. The high melting point and electrical resistivity of this ash, 10-11 Ω.m at 140-180°C, make its removal difficult. Effective ash removal requires lowering the temperature of flue gases to 100°C or lower and maintaining that temperature, which is achievable by ensuring their sufficiently low velocity and sufficiently long treatment time in the electric filters designed for this purpose. Another problem is lowering the concentration of nitrogen oxides in the smoke. Several schemes have been developed for accomplishing this, following both a theoretical analysis based on mathematical models and an engineering analysis based on feasibility criteria. The two schemes selected for practical implementation are: 1) two-tier arrangement of vortex burners and three-stage fuel combustion in a tangential furnace chamber with reduction of the NO_x content in the flame regions near auxiliary uniflow burners installed one behind the other, 2) stagewise fuel combustion in the horizontal plane of a two-vortex furnace with a 65% of secondary air fed at an angle to the jet of air an coal dust mixture. For an ecologically clean operation of 500 MW electric power plants with Ekibastuz coal is furthermore recommended extraction of SO_2 from the flue gases by means of an absorber and combining it with wet lime to produce gypsum. A comparative performance analysis of the existing Ekibastuz regional electric power plant and this ecologically clean one confirms the very significant advantages of such a plant with respect to air pollution standards. Figures 6; tables 5.

Prospective Steam-Gas Units With Gasification of Kansk-Achinsk Coal in Ecologically Clean Berezovo GRES-2 Regional Electric Power Plant

927F0021C Moscow TEPLOENERGETIKA in Russian No 6, Jun 91 pp 18-24

[Article by P.A. Berezinets, candidate of technical sciences, V.I. Gorin, candidate of technical sciences, Yu.V. Nesterov, candidate of technical sciences, V.P. Semenov, candidate of technical sciences, A.I. Yegorov, engineer, V.M. Ivannikov, engineer, V.N. Blagorodov, engineer, G.Ye. Kosinskiy, engineer, and V.S. Meshalkin, engineer, All-Union Institute of Heat Engineering; State Scientific Research and Planning Institute of the Nitrogen Industry and Products of Organic Synthesis; Krasnoyarsk Regional Administration of Power System Management, RSFSR Institute of Planning Electrical Equipment for Heat Engineering Installations]

UDC 621.438:621.11.001

[Abstract] Gasification of Kansk-Achinsk coal in the Berezovo GRES-2 regional electric power plant is proposed as a means of reducing the nitrogen and sulfur content for ecologically clean operation of this and any other electric power plant. Gasification of dry coal under pressure in an oxygen stream has been selected in preference to gasification in a dense or fluidized bed. The apparatus for coal gasification in a steam-gas plant is designed to treat brown coal with a maximum 38% moisture content and a maximum 7.4 ash content, with a calorific value of 13.6 MJ/kg, and a 0.3% sulfur content. Coal dust treated in this apparatus has an only 10% moisture content and yields 1.59 m^3/kg gaseous fuel with a calorific value of 9.39 MJ/m^3. The gasifier is to operate in a binary steam-gas power plant consisting of two 200 MW gas turbines (inlet temperature 1250°C), two boilers with recuperators, and one 300 MW steam turbine. Raw coal is fed from a closed explosion-proof storage house furnished with a dust inhibitor into steam-operated dryers which reduce its moisture content from 38% to 15% with the aid of steam from the low-pressure stage of the turbine plant. From here it is fed into roller mills for crushing and further reduction of the moisture content to 10%. Nitrogen, a by-product of oxygen generation in the air distributor, is heated to 200-220°C by air from the gas-turbine compressor and fed into the roller mills to serve as both drying and ventilating agent. Coal dust and nitrogen are subsequently separated, nitrogen being dumped into the steam dryers for saturation with

water vapor and coal dust being dumped into a bunker. Oxygen for coal dust gasification is produced by low-temperature rectification distillation of liquid air in a cryogenic air distributor. The gasifier consists of a reactor and a radiative cooler. The reactor with overhead burners gasifies the descending coal dust jet operates at a 1800- 2200°C temperature in the flame core, the temperature dropping to about 1500°C at the outlet but remaining here higher than that of the liquid slag. The cooler lowers the temperature of the coal gas to within 900- 700°C. The coal gas is purified of coal dust to a lower than 10 mg/ m^3 residual concentration of the latter without any particles larger than 10 μm, whereupon it is first cooled to 150°C in a gas-to-gas heat exchanger and then water-cooled to 40°C while also being dried in a contact heat exchanger. Ash, one of the waste products, is converted into industrial-grade granular slag. Hydrogen sulfide evolving during sulfur removal is fed into a Klaus apparatus, which converts it into commercial-grade sulfur by a low-temperature process not requiring use of lime or limestone. Operation of this apparatus lowers the overall plant efficiency, owing to added heat losses, but is very efficient inasmuch as it removes least 98% of all hydrogen sulfide. The proposed gasification technology thus not only dispenses with supplementary materials, thus eliminating many delivery and storage problems, but also facilitates economical disposal of waste products by turning them into useful ones. Figures 2; tables 1.

Steam-and-Gas Plant With Circulating-Fluidized-Bed Boiler Under Pressure for Combustion of Low-Grade Coals

927F0021D Moscow TEPLOENERGETIKA in Russian No 6, Jun 91 pp 24-29

[Article by R.Yu. Shakaryan, candidate of technical sciences, P.A. Berezinets, candidate of technical sciences, R.A. Petrosyan, candidate of technical sciences, Ye.V. Shchukin, candidate of technical sciences, and I.I. Nadyrov, engineer, All-Union Institute of Heat Engineering]

UDC 621.165+6211.438

[Abstract] Scientific research and experimental design activity has been underway since 1987 toward development of circulating fluidized beds for boilers in steam-and-gas plants burning anthracite culm, this fuel now containing 21% or more ash not readily removable by slag formation so that conventional methods of emissions abatement are ineffective here. Thorough combustion of this dusty fuel requires a long residence time in the furnace and thus an intense circulation of small particles inside the furnace to ensure their entrapment with a high integral as well as fractional efficiency. A "hot" cyclone repeatedly circulating the ash at 850-900°C has accordingly been installed in the furnace for a boiler generating 13.8 MPa - 560°C steam at a rate of 500 t/h to drive a T-115-130 turbine, the reducing lower zone of the fluidized bed becoming thermally stabilized by this cyclone. Into the furnace is also fed limestone or dolomite in an amount ensuring a Ca:S = 2.5 ratio and limiting emission of sulfur oxides to 200 mg/m^3 at 900°C, while air injected in three stages lowers the combustion temperature and thus limits the production of nitrogen oxides to 200 mg/m^3. The furnace with a circulating fluidized consists of two chambers with a common vertical shaft for convective heat transfer. The advantages of this system are economical combustion of high-ash and low-grade coals without gas or oil primer, low emission of sulfur and nitrogen oxides in accordance with clean air standards, compact configuration and high energy efficacy of the power unit. These advantages have been maximized in the new design of a boiler with a circulating fluidized bed under pressure, a dense bed containing a fluidized layer turbulized into bubbling by injection of a air sufficiently far below the surface so as to prevent its heating at air velocities of 1.5-3.0 m/s while ensuring that the fuel and the ash sorbent are thoroughly mixed. Air injection in three or four stages facilitates low-temperature combustion at 850°C and thus limits emission of nitrogen oxides to 200 mg/m^3 or less. Complete combustion of the fuel is effected owing to intense circulation of ash and its sorbent inside the furnace, the thus extracted ash becoming a useful by-product tying up as much as 90% of the sulfur oxides otherwise emitted into the atmosphere. A boiler with such a furnace has been installed in a 270 MW steam-gas power plant with a GTE-45-2 gas turbine built at the Kharkov Turbine Manufacturing Plant and a K-225-12.75 built at the Leningrad Metal Works. Ash, dry upon its removal from the boiler in three scrubbing cycles, mixes with sulfates produced by reaction of SO_2 with the ash sorbent. This mixture can be used for production of useful materials such as silicate brick and gas concrete. Figures 6; tables 2.

Selected Results of Engineering Activity of USSR Minenergo in 1990

927F0022A Moscow ELEKTRICHESKIYE STANTSII in Russian No 7, Jul 91 pp 2-7

[Article by V.Ye. Denisov, engineer, All-Union State Trust for the Organization and Rationalization of Rayon Electric Power Plants and Systems]

UDC 621.31

[Abstract] As in previous years, in 1990 the All-Union State Trust for the Organization and Rationalization of Rayon Electric Power Plants and Systems [ORGRES] received information regarding the operating reliability and economic indicators characterizing the sector's power generation systems and enterprises. This information was received from all power generation and electrification production associations and directly from a significant number of electric power plants. The following are some highlights of the information received. In 1990, 1,429.3 billion kWh of electric power was

produced at the electric power plants under the supervision of the USSR Minenergo. This is 6.5 billion kWh more than in 1989. Production at TES dropped by 3.2 billion kWh to 1,197.8 billion kWh, thus resulting in a 1.1-million ton reduction in the consumption of fuel equivalent. The absolute increase in the production of electric power with respect to the power-and-heating cycle increased by 1.9 billion in 1990, thus reaching 279 billion kWh and accounting for 23.3% of all electric power produced. TES produced 983.5 million Gcal heat (a 1.1% increase over 1989). Improvements in the power-and-heating cycle thus resulted in a fuel savings of about 0.75 g/kWh. A reduction in the economy of producing electric power based on a condensation cycle (due to operations problems) resulted in an overconsumption of 0.62 g/kWh, however. Equipment with a capacity totaling 4,361 MW was introduced at TES in 1990 (only 56.7% of the yearly plan), and equipment with a capacity totaling 580 MW (45% of the planned amount) was introduced at GES. The biggest problems related to power generation at TES in 1990 were a low level of heat consumption (mainly due to turbines with backpressure), a shortage of cooling devices, a deterioration of the condition of boiler equipment, and the burning of non-design or reduced-quality fuel. A drop in 1990 power generation unit reliability indicators from their 1989 levels was noted for 200-, 500-, and 800-MW units. The indicators of units with capacities of 250 to 300 MW remained at their 1989 levels. Turbogenerators with hydrogen cooling were found to present the greatest fire hazard. The qualitative distribution of equipment failures and their causes remained virtually unchanged from the 1989 data. About 80% of all failures were attributed to pipes, and more than half of all pipe failures were due to outside corrosion. Most pipe failures occurred on pipes with an operating time of 200,000 hours and resulted from a failure to replace pipes on time. At the beginning of 1990, about 12% of all overhead power lines had been in use for over 30 years. The susceptibility to damage of 6- to 10- and 25- to 110-kW power lines in 5 years increased by a factor of 1.3. Design, manufacturing, and installation defects were responsible for most failures occurring in electrical networks. A drop (by a factor of 7.3) occurred in the number of disruptions in the operation of electrical equipment and transmission lines between August and December as compared with the previous year. This drop was attributed to changes in accountability requirements instituted in August 1990, however. The number of modernization measures taken in 1990 totaled 632, including the following: 479 on boilers, 115 on turbines, 30 on generators, and 8 on transformers. According to preliminary data, the savings from these efforts will total 10 million rubles and 250,000 tons fuel equivalent. Measures were also taken to reduce electric power losses within the system. The plan called for reducing losses in the amount of 1.3 billion kWh; in reality, 0.083 billion kWh of losses were prevented. This means that 1990 losses should amount to about 133.25 billion kWh or 8.65%. In 1990, GES produced 231.3 billion kWh of electric power (nearly 10 billion more than in 1989), and at the end of 1990 they had an installed capacity of 64.4 million kW. Three new hydroelectric generating units were put into operation (one each at the Krivorog GES (capacity, 45,000 kW), the Shulbinsk GES (capacity, 117,000 kW), and the Zagorsk GAES (capacity 200,000 kW)). Serious reliability problems at GES, related to outdated equipment that is over 30 years old in many cases, make their refurbishing and redesign between 1991 and 2000 a critical issue. Tables 2.

Construction and Improvement of Gas Turbine Engines

927F0025A Moscow PROBLEMY MASHINOSTROYENIYA I NADEZHNOSTI MASHIN in Russian No 3, May-Jun 91 pp 31-36

[Article by I.A. Birger, Moscow]

UDC 621

[Abstract] A family of gas turbine engines for civil aviation, for subsonic flights at speeds up to 1000 km/h and supersonic speeds above 2000 km/h, has been developed and built by the Scientific-Industrial Association "Trud" [Labor] with Academician Nikolay D. Kuznetsov as chief engineer. The design of these engines, accordingly marked as type NK, is improved. Those of the NK-12 class, built for the longest-range modern airplanes such as the TU-114, have a 14-stage compressor running at 88% efficiency and a 5-stage turbine running at 0.94% efficiency. Two important features of this engine are vanes made of a cast rather than wrought heat-resistant material and a 12,000 hp speed reducer with a floating fit for the central gear, each of these features being an unconventional ultimate solution to a difficult problem which has engaged several successive teams of engineers. A 25,00 hp speed reducer with the same type of planetary gear train is now being designed for a turbofan engine. Engines of the NK-8 class have a takeoff thrust capacity of about 105 kN and are very reliable, the NK-8-2U dual-cycle jet engine being built for TU-154 passenger planes. This engine has a compressor with many parts made of titanium and a new type of combustion chamber with a uniform temperature distribution. The last engine in this class is the NK-86 with a takeoff thrust capacity of 127 kN, sufficient for an air bus carrying 350 passengers. Further innovations include dual-cycle engines with three shafts for optimum matching of turbine and compressor stages, directional solidification of molten metal for subsequent casting of vanes from a single crystal each so as to additionally increase their durability as well as mechanical strength, and multicomponent surface coatings which prevent high-temperature oxidation of vanes. Another new engine is the NK-92, which features not only a takeoff thrust capacity of 200 kN and a 25,000 hp speed reducer for the propellers but also a very favorable fuel (gasoline) economy within the 14-16 g per passenger-km range. Figures 2; references 3.

Ensuring Reliability and Long Life of Gas Turbine Engines

927F0025B Moscow PROBLEMY MASHINOSTROYENIYA I NADEZHNOSTI MASHIN in Russian No 3, May-Jun 91 pp 37-44

[Article by V.N. Tseytlin, Kuybyshev]

UDC 624.03:629.13

[Abstract] Gas turbine engines for civil aviation built by the Scientific-Association "Trud" [Labor] with Academician Nikolay D. Kuznetsov as chief engineer Academician Nikolay D. Kuznetsov include five models (NK-12, NK-12MV, NK-8-4, NK-8-2U, NK-86, NK-144) installed on TU-144, TU-144, TU-154, Il-62, IL-86 passenger airplanes and two models (NK-12ST, NK-16ST) convertible for pumping natural gas over pipelines. Their common feature is high reliability and long life, up to 18,000 h (NK-8-4) and 30,000 h (NK-16ST), built into them in their design and mode of operation. Their design was targeted on satisfying seven groups of performance criteria (altogether 648 for the NK-8-4 engine): parametric, functional, and technological characteristics; strength characteristics; operating, repairability, and maintenance characteristics. The parametric criteria were short-time performance indicators characterizing the resistance of engine materials under a one-shot load (yield strength, ultimate strength, percent reduction and elongation prior to rupture, impact strength measured in notch or crack tests, stress intensity coefficient indicating the degree of ductility of fracture), high-strength corrosion and erosion resistant materials having been selected for engine parts along with appropriate methods of hardening the latter, and long-time performance indicators depending on the load duration (strength under continuous load, creep limit and relaxation time, high-frequency and short-cycling fatigue strength, resistance to cracking, wear and corrosion resistance). Design calculations were based on high-level mathematical models of stress and strain under real loads encountered in service. The safety margin was determined on the basis of cumulative defectiveness under diverse composite loads. Methods of structural vibration damping and of detuning from resonances were devised for use in the assembly process. The design procedure provided for extensive experimental study of all design factors, including full-scale reliability and life testing of all engine components prior to assembly. Four kinds of special tests were performed under conditions as closely as possible approaching various real service conditions. Vibration tests were performed on housings and runners for determination of natural frequencies, critical speeds, torsional displacements, and stress distributions. Heating tests were performed on fuel and lubricant for determination of their temperature rises and thermal stability. The lubrication system was tested for circulation and heat transfer. Stability tests were performed on engines under transient and steady-state conditions with the fuel regulation system set at extreme levels, for stability margins and reliability under extreme and anomalous operating conditions such as excessively high runner speed or gas temperature, also for reliability during ingress of rain, ice, sand, gravel, debris, and birds. The engines not only have necessary features for ensuring reliability and long life built into them but are also equipped with automatic controls including fault detectors and alarm signals. Lights on the control panel indicate dangerous conditions such as lubricant underpressure, lubricant contamination by dust or metal chips, overheated bearing or overheated working gas, and excessive vibration. These controls will become more extensive as the complexity of newer engine models increase. Figures 4; tables 2.

Preliminary Setup of Parts for Automatic Assembly of Joints With Redundant Connections

927F0025C Moscow PROBLEMY MASHINOSTROYENIYA IN NADEZHNOSTI MASHIN in Russian No 3, May-Jun 91 pp 87-91

[Article by I.A. Koganov, Ye.A. Voskresenskiy, and V.V. Semin, Tula and Moscow]

UDC 621.757

[Abstract] The problem of connecting parts at several surfaces and ensuring interchangeability is considered, connecting a machine tool to the saddle and threading two pipes for a scarf joint being typical examples of this problem. A matching procedure is proposed for subsequent joining on the assumption that not only parts from lots designated by the same number but also parts from adjacent lots can be set up for assembly, a design of the matching operation by the group interchangeability method being hardly feasible here while a design based on the theory of probability theory does not allow significant widening of the tolerances on the few dimensions involved. The matching process according to the proposed procedure reduces to maximization of the sum $\Sigma_{i-1}{}^{n}\beta_i$ (β- mating coefficient dependent on the involved allowance and surface area, n- number of connections to be made). There are three possible variants of this procedure, each leading to a different level of match optimization. The first one yields a match which maximizes the estimator sum $\Sigma_j{}^{r}\Sigma_{i-1}{}^{n}\varepsilon_i\ \beta_i$ (ε- numerical coefficient representing the relative amount of matching effort, r- number of setups for assembly). The second variant matches each part with its best fitting "partner" and thus also maximizes this sum. The third variant ensures that this sum will not be smaller than prescribed for each setup. Preparation of input data for optimum matching requires specification of the manufacturing tolerances on all parameters of a joint, specification of the number of size groups into which the lot of parts needs to be subdivided prior to assembly, and specification of the optimum difference between mean deviations of the matched parts from perfect. The algorithm of matching is demonstrated on the simplest case of two parts such as two pipes or breech and barrel of a hunting rifle. It has been programmed for computer-aided automatiion of the matching process when the number of parts to be joined is large. Figures 5; references 2.

An Investigation of the Supersonic Circulation of Bodies at Low Altitudes With Consideration for Radiation

927F0024E Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 3, May-Jun 91 (manuscript received 28 Nov 88) pp 182-184

[Article by E.Z. Apshteyn, V.I. Sakharov, and A.V. Shevoroshkin]

UDC 533.6.011:536.24

[Abstract] Others have examined supersonic nonviscous circulation by radiating air of bodies with various shapes and dimensions at altitudes of ≥ 40 km at flight speeds of 7 km/s $\leq V_\infty \leq$ 40 km/s in the earth's atmosphere. The said researchers established that the distribution of the relative radiant heat fluxes to the surface of blunted bodies is weakly dependent (at the given velocity V_∞) on the flight altitude and the size and shape of the body. In a continuation of this line of research, the authors of the study reported herein examined the same problem but at altitudes ranging from 0 to 40 km, i.e., given higher gas densities and optical thicknesses in the shock layer. The authors of the present study used flight speeds in the range 12 km/s $\leq V_\infty \leq$ 15 km/s and a shock wave optical thickness of $\tau_{vs} << 1$ to $\tau_{vs} >> 1$. They discovered significant distinctions in the behavior of radiant heat fluxes to the surface of circulated bodies at low altitudes. The first case considered the bodies were spheres that were so small that radiation had no bearing on the gas dynamic parameters of the shock layer; the optical thickness of the spheres was $<<1$. As flight altitude decreased, the curves of the relative flows shifted downward. The shift was especially dramatic for altitudes of about 40 km. At low flight altitudes, the drop in temperature around the rim of the circulated body and the change in the radiant heat flux were found to be greater at low flight altitudes. Differences were also discovered in the way in which the shape of the circulated body affects the distribution of the relative radiant heat fluxes [$q(\theta_s)$] at low and high flight altitudes. The curves of $q(\theta_s)$ for altitudes between 40 and 80 km and for bodies less than about 10 m in size are weakly stratified. At flight altitudes below 40 km, however, there is a strong stratification of the curves plotted for $q(\theta_s)$. The authors accounted for this behavior and also managed to establish that the stratification of the $q(\theta_s)$ curves becomes insignificant if the binary similarity parameter $\rho_\infty R$ is preserved. It was also discovered that when R is approximately 1 cm or greater, the heat flux to the critical point diminishes as the size of the body increases and then becomes constant when $R \simeq 1$. For a flight altitude of 65 km at a flight speed of 12 km/s, on the other hand, the maximum heat flux to the critical point is reached at $R > 10^3$ m. Figures 2; references 5 (Russian).

The Nonstationary Aerodynamic Interaction of Two Annular Blade Rows of Thin Lightly Loaded Vanes as They Rotate Relative to One Another in a Subsonic Field

927F0024D Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 3, May-Jun 91 (manuscript received 8 Dec 89) pp 165-174

[Article by K.S. Reyent, Moscow]

UDC 533.697.242.011

[Abstract] The author solves the problem of the subsonic circulation of two annular blade rows of thin weakly loaded vanes that are rotating in relation to one another and that are circulated by ideal gas. The problem is approached within the linear theory of perturbations, and as in the case of the interaction of plane lattices, he has reduced the problem to an infinite system of singular integral equations for the harmonic components of the fluctuations in the distribution of an unknown aerodynamic load on one blade of each row. The colocations method is used to obtain a numerical solution to the integral equation system for a finite number of harmonics. A method that was initially proposed elsewhere is used to regularize the kernel of the integral equations. The differences between the three-dimensional nonstationary interaction of two blade rows and plane lattices are discussed. Specifically, the nonstationary flow in a stage results from the presence of inhomogeneous stationary fields (each with their own system of coordinates) after the first blade row (lattice) and before the second blade row (lattice) is examined individually. In the plane scenario, the flow passing through the profile lattice diverges sufficiently far from the lattice so as to be considered virtually homogeneous; the inhomogeneities existing close to the lattice attenuate quickly as the distance from the lattice up and down along the flow increases. The differences between the results achieved by a computation program based on a three-dimensional program and the results obtained by using a cylindrical computation program are also compared. The author states that the semianalytical approach used in the analysis reported herein has a number of important advantages when compared with numerical solutions. He further states that both the analytical relationships derived in solving the problem and the actual results themselves may be used to obtain information regarding the qualitative characteristic features of a nonstationary three-dimensional flow that can in turn be used to improve the direct numerical calculation of flows in actual highly loaded turbines. Figures 4; references 9: 4 Russian, 5 Western.

The Intersection of Shock Waves in Magnetohydrodynamics

927F0024C Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 3, May-Jun 91 (manuscript received 30 Oct 90) pp 132-144

[Article by A.A. Barmin and Ye.A. Pushkar, Moscow]

UDC 533.6.011.72:537.84

[Abstract] The authors of the study reported herein examined the flow formed in the vicinity of the point of intersection of the discontinuities during the head-on collision of shock waves with a nonzero angle between them. They considered the problem of the intersection of two fast shock waves in a quasi-stationary formulation. They perform their calculations over a wide range of parameters so as to be able to examine cases of shock wave interaction that are of interest when analyzing phenomena in near space and solar wind. Specifically, they specified the Mach numbers M_1 and M_1' equal to 1.2, 1.5, 2.0, 3.0, 5.0, and 8.0 such that $M_1' \leq M_1$. The angle between the shock waves (θ) was varied from 10° to 50-120° at 10° intervals, and Alfven numbers of 0.7, 1.1, 1.5, 2.0, and 2.5 were used. The slope of the magnetic field was varied from 15 to 165° at 5-15° intervals. The Mach numbers of the flow and arriving waves were selected so as to encompass the entire range of their variation in solar wind. The results of the numerical analysis performed were processed in the form of various tables and diagrams so as to represent the qualitative form of the flow and order of magnitude of the dynamic effect that each of the waves forming the flow have on the medium. The authors also described the main qualitative features of the flow resulting from the interaction of two shock waves under the conditions studied. They concluded that the term "intersection" can only be used loosely in connection with the interaction of shock waves because what actually occurs when two shock waves meet is that each of the two waves decays. Two types of interactions, i.e., quasi-parallel and quasi-perpendicular, were identified. In the former, the intensity of the generated fast waves was on the order of the incident waves; they are shock waves. The slow waves are weak. In the case of a quasi-perpendicular interaction, the type and intensity of all of the waves changed significantly depending on the angle ψ. The authors also identified several restructurings that may occur in the event of global catastrophes and summarized their parameters in table form. A change in just the orientation of the magnetic field behind one of the interacting shock waves was found to result not only in a strong change in the field but also in a change in the pressure and velocity throughout the entire flow. Other types of qualitative restructurings of the flow were found to be caused by the coincidence of the characteristic speeds, i.e., an Alfven speed with a fast speed and a slow speed with a magnetosonic speed. Several varieties of these restructurings were examined as different types of local catastrophes. Two types of "discontinuity" catastrophes involving the merging of Alfven and fast (slow) characteristics behind the fast (before the slow) rarefaction wave were also identified and discussed. The changes in physical quantities that occur during all of these types of catastrophes given different initial parameter values were examined and detailed in table form. The authors also examined the effect of that the magnetic field (the parameters N and ψ) and the angle θ between the colliding waves have on the change in the physical quantities in a flow. They discovered, for example, that the angle ψ has a strong effect on the resulting gas dynamic pressure (p_4). This effect was most pronounced in moderate fields. They also found that the magnetic field intensity increases greatly in the quasi-parallel case but remains virtually unchanged in the quasi-perpendicular case. Intensification of the field was found to be greater at small θ than at large θ. The following are among the other differences that were found to exist between quasi-parallel and quasi-perpendicular interactions: In the quasi-parallel case, the magnetic field smooths the pressure rise, reduces the increase in the speed of the medium, and increases strongly itself. In the quasi-perpendicular case, the magnetic field compresses the case and accelerates it: The energy of the magnetic field is transformed into thermodynamic energy and the energy of the directed motion of the medium; the intensity of the magnetic field changes only weakly. The authors recommended that the various dependences they derived be used in studying the interaction of a solar wind shock wave with a bow shock wave around the earth. Figures 6, tables 5; references 15: 7 Russian, 8 Western.

Heat Transfer on a Cylinder Circulated by a Hypersonic Flow in a Zone of Shock Wave Impingement

927F0024B Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 3, May-Jun 91 (manuscript received 16 Apr 90) pp 117-123

[Article by V.Ya. Borovoy and I.V. Struminskaya, Moscow]

UDC 533.6.011.72+532.526.2

[Abstract] Intensive research on shock wave interference has been underway since the 1960's. The research that has been conducted indicates that heat transfer increases sharply as the Mach number (M_∞) increases. To date, however, heat transfer experiments have only been conducted at M_∞ up to 6. Experiments involving higher M_∞ have only been conducted in a helium flow. The authors of the study reported herein conducted systematic experimental research in a zone of shock wave interference with a laminar boundary layer in an air flow at M_∞ = 15.5. The experiments encompassed gliding angles so as to consider various shock wave interactions. The experiments were conducted by using a cylinder 25 mm in diameter with hemispheres of the same diameter mounted on its ends so that the total length of the model came to 205 mm. A sharp wedge with a beamwidth of 20° was used as the shock wave generator. The lower surface of the wedge was parallel to the direction of the undisturbed flow, and the upper surface induced the shock wave. Its slope at the point at which it fell onto the cylinder equaled 27°. The cylinder was prepared with 60 heat flux transducers arranged along the critical line in accordance with the "thin-wall" method. The thin wall was made of stainless steel foil 0.17 m thick and 7 mm

wide. Thirty transducers were spaced 1 or 2 mm apart at the point where the shock wave fell; another 30 transducers were placed 5 mm apart along the rest of the cylinder. The random error in measuring the density of the heat flux was estimated at 12%. The experiments were conducted in a shock tube at a total pressure of $p_0 = 50 \times 10^5$ Pa, an impact temperature of 1,650 K, $M_\infty = 15.5$, and a Reynolds number of 0.14×10^5. The boundary layer was in a laminar state. A profiled nozzle with an outlet cross sectional diameter of 400 mm and nucleus diameter of 180 mm was used. The flow in the experimental chamber of the wind tunnel was calculated to last 7×10^{-3} s. The various types of reactions occurring at different values of χ were discussed in accordance with Edney's 1968 classification. The type 1 interaction, i.e., the regular interaction of shock waves of different families, occurred when χ was between -75 and -53°. A type 2 interaction began at $\chi = -53°$. A bridge-like system of jumps with two nodal points forms, and the jumps extending from these points fall onto the cylinder's surface. Type 3 interactions, which are characterized by the fall of a mixing layer onto the body, were not identified in the experiments conducted. This was attributed to the fact that such interactions only exist in a very narrow range of slopes of the gliding cylinder. Type 4 interactions were observed to occur in the range of gliding angles between -22° and 7° and were characterized by the formation of a supersonic high-pressure stream inside the subsonic flow that fell onto the body's surface at an angle close to 90°. Type 5 reactions occurred in the gliding angle range $14 \leq \chi \leq 30°$. They were characterized by the fact that the shock wave AI_1 departing from the point of the Mach interaction of the shock waves falls onto the cylinder's surface. Type 6 interactions were observed to form at gliding angles of $\chi \geq 37°$. These interactions involved the formation of rarefaction waves from the point at which the shock waves intersect. As in a type 5 interaction, the successive compression of the gas in the incident and bow wave results in an intensification of heat transfer. The pressure peaks and heat flow characteristic of a type 6 interaction are lacking in the type 5 interaction, however. The different types of interactions were associated with very different flow structures. These changes in the flow structure lead to a sharp change in the nature of the dependence of the density of the heat flux on the cylinder's glide angle. The ratio of the maximal heat flux to the heat flux on an isolated cylinder as determined at the same gliding angle was found to reach its maximum in the case of type 1 interactions. The ratio of the maximal heat flux to the heat flux on an isolated cylinder as determined at a zero gliding angle reached its maximum value in the case of a type 4 interaction, however. At gliding angles with an absolute value of ≤ 30, the discrepancy between the experimentally obtained and calculated values amounted to about 7%. At gliding angles with higher absolute values, the discrepancy was found to increase to 15-23% of the measured value. Figures 5; references 11: 8 Russian, 3 Western.

A Three-Dimensional Boundary Layer on a Flat Delta Wing in a Mode of Moderate Interaction With a Hypersonic Flow

927F0024A Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 3, May-Jun 91 (manuscript received 5 Jun 90) pp 110-116

[Article by G.N. Dudin, Moscow]

UDC 533.6.011.55+532.526

[Abstract] The author has calculated the three-dimensional boundary layer on a flat delta wing of finite length in a mode of moderate interaction with an external hypersonic flow and has examined the effect of the hypersonic parameter of the interaction on the flow of gas in the boundary layer and on the aerodynamic characteristics. Previous researchers have established that in the case of hypersonic circulation of thin delta wings, the nature of the flow in the boundary layer is largely dependent on the size of the hypersonic parameter of the interaction as determined on the basis of the density and velocity of the gas in an undisturbed flow, the length of the wing, and the viscosity coefficient at the impact temperature. Yet other researchers have shown that the interaction of an external nonviscous hypersonic flow with a boundary layer may result in the separation of the boundary layer, the appearance of strong transverse flow, and a very uneven distribution of the heat flux to the body's surface. It has further been shown that the total aerodynamic characteristics vary significantly depending on the mode of interaction. Several other publications have demonstrated that for the case of a strong interaction between a delta wing and a hypersonic flow, it is possible to reduce the boundary value problem to a self-similar problem that can be solved by the methods that have been developed to solve two-dimensional problems. The same cannot be done in the case of moderate interaction that is considered in the present article. The calculations performed by the author show that the pressure distribution and value of the coefficient of friction stress in a lengthwise direction (τ_u) change significantly depending on the size of the interaction parameter (χ_*). As in a mode of strong interaction, in the case of moderate interaction considered herein, the effect of the trailing edge is extended upward along the flow to approximately 30-40% of the chord of the wing. The significant reduction in pressure (p) in the region of $x = 1$ when $\chi_* = 1$ results in acceleration of the flow in a lengthwise direction and in an increase in τ_u. The heat flux changes analogously. Increasing the temperature factor was found to have a significant effect on the flow parameters. The calculations performed also indicated a significant increase in the total aerodynamic characteristics as the parameter χ_* was decreased from 10 to 1. When flows with $\chi_* > 10$ were considered, the aerodynamic characteristics did not change; instead, they practically coincided with those corresponding to a mode of strong viscous interaction. Figures 4; references 9: 8 Russian, 1 Western.

Elementary Wave Propeller

927F0008A Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 318 No 4, 11 Jun 91 pp 849-852

[Article by V.P. Boldin, A.I. Vesnitskiy, and Ye.Ye. Lisenkova, Institute of Machine Design imeni A.A. Blagonravov, Nizhegorodsk branch, USSR Academy of Sciences]

UDC 531/534

[Abstract] The principle of a wave propeller, a device which converts the energy of a power source into work of driving objects by the mechanism of wave formation, is analyzed so as to demonstrate the feasibility of an "elementary" one which emits waves in one direction only in addition to being a "point" propeller much shorter than the wavelength. As driven object is considered a lumped one with mass m and moment of inertia J_0 freely moving along a beam, on this object acting a transverse force P(t) and a moment M(t) which vary in time. The motion of the object along the beam is then described by the equation $ml^2l/dt^2 = -[T - pdl/dt] + R(t)$. In this equation the net force [T - pdl/dt] represents the difference between the two wave pressure forces acting from opposite sides of the moving boundary x = l(t), namely the force associated with the wave momentum flux $T = (\rho u_t^2 + JEu_{xx}^2)/2 - JEu_xu_{xxx}$ and the force associated with the wave momentum density $p = -\rho u_tu_x$. The third force R(t) represents resistance to the motion, and the transverse deflection of the neutral beam axis u(t,x) satisfies the Bernoulli-Euler equation $JEu_{xxxx} + \rho u_{tt} = 0$. Assuming a uniform motion of the object, namely [T- pdl/dt] = R(t) so that dl/dt = v = const and $md^2/dt^2 = 0$, the system of these two equations is solved under the constraint of finite beam deflection and no wave sources at infinity. The condition for optimum propulsion of the object under pressure forces is shown to be unidirectional emission of waves, it thus becoming evident that an elementary wave propeller must have two kinds of coherent radiation sources supplying respectively in-phase and antiphase forward and backward waves. Interference of the waves from both sources will produce a unidirectional radiation pattern and the reaction force will then propel the object in the opposite direction. A lumped propeller with unidirectional wave emission is shown to be also feasible in a dispersionless system such as a string subject to only one transverse force, even though such a system apparently does not belong in this class. Article was presented by Academician K.S. Kolesnikov on 2 January 1991. Figures 4; references 2.

Diffraction of Longitudinal Wave by Rigid Elliptical Cylinder

927F0008B Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 318 No 4, 11 Jun 91 pp 857-861

[Article by N.I. Aleksandrova, Institute of Mining, Siberian Department, USSR Academy of Sciences, Novosibirsk]

UDC 539.3

[Abstract] Interaction of an infinitely long rigid elliptical cylinder in an elastic medium and a plane longitudinal compression wave obliquely incident at some angle to the major axis of the cylinder cross-section is defined as a two-dimensional transient-state problem of a plane incident compression front parallel to the cylinder generatrix and is formulated in an elliptical system of coordinates ξ,η with the origin on the cylinder axis. Motion of the elastic medium is described by two two-dimensional wave equations for the scalar and vector displacement potentials respectively. The problem is split into two additive parts $Y = Y^0 + Y^1$, where Y^0 denotes the vector with stress components $\sigma_{\xi\xi}{}^0$, $\sigma_{\eta\eta}{}^0$, $\sigma_{\xi\eta}{}^0$ and displacement components $u_\xi{}^0$, $u_\eta{}^0$ while Y^1 represents reflected and diffracted waves. The problem is solved with the aid of a Laplace transformation and a subsequent series expansion in Mathieu functions under the constrain of no radiation at infinity. The exact solution is, after successive simplifying transformations, obtained in the form of double sums $\Sigma_{n=0}{}^\infty\Sigma_{i=1}{}^4$ of terms representing stresses implicitly. Inasmuch as explicit expressions for the stresses cannot be analytically obtained, an asymptotic solution for them at time t >> 0 but finite and then $t \to \infty$ is obtained instead by letting p be a small parameter. Article was presented by Academician Ye.I. Shemyakin on 31 January 1991. Figures 1; references 2.

Loss of Stability by Cylindrical Shells Under Nonuniform Axial Compression

927F0012A Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 318 No 6, 28 Jun 91 pp 1325-1327

[Article by Academician A.V. Pogorelov, Institute of Low-Temperature Engineering Physics, UkSSR Academy of Sciences, Kharkov]

UDC 539.3

[Abstract] Loss of stability by a circular cylindrical shell under nonuniform axial compression is analyzed by the author's geometrical method (DOKLADY AKADEMII NAUK Vol 304 No 5, 1989) in a curvilinear system of coordinates u, v (u- distance along the generatrix, v- angle of rotation about the shell axis), assuming that the shell rests on free supports and the radial component of its deformation is consequently zero. Compressive forces $q_1(v)$ and $q_2(v)$ are acting at its two edges $u = a_1$ and $u = a_2$ respectively. A special infinitesimal deflection τ of the median surface is introduced with a discontinuity along a closed line γ: u = u(v). The deformation energy U and the work A of the load force in so deflecting the shell under the given constraints are calculated, the critical load then being determined from the condition that the minimum with respect to τ ratio U/A be equal to 1. The resulting expression for the critical load indicates that loss of stability begins with local buckling in the vicinity

of the point (u, v) where that ratio and thus also the critical are minimum. Figures 1; references 1.

Stability of Laminate Half-Plane in Regular Structure Under Omnilateral Compression

927F0013A Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 27 No 8, Aug 91 pp 16-22

[Article by A.N. Guz, V.P. Korzh, and V.N. Chekhov, Institute of Mechanics, UkSSR Academy of Sciences, Kiev]

UDC 539.3

[Abstract] A multilayer medium with a semi-infinitely long regular structure between two perfectly rigid stationary walls and under a uniformly distributed "dead" or "tracking" load of intensity p_3 on its free surface is considered, when such a load is compensated at "infinity" only and when the medium makes frictionless contact with the two walls. Each half-plane layer of the medium is then in compression by a uniformly distributed load of intensity p_1, equal or not equal to p_3, so that the strain component ε_{11} is zero within that layer. The medium is referred to Lagrangian coordinates x_i which coincide with Cartesian coordinates prior to deformation of the medium. The boundary conditions are rigid contact between contiguous layers of the medium and complete decay of displacement vector perturbations at "infinity" ($u_j \to 0$ as $x_3 \to -\infty$). The stability problem for such a medium in a plane state of finite subcritical strain under these conditions is treated in accordance with the linearized three-dimensional theory of stability for piecewise-homogeneous media. It is solved by first representing the components of displacement vector and stress tensor perturbations in matrix form, then representing the boundary conditions in the form of matrix equations. The problem is finally reduced to the matrix equation Σ_{i-1}^2(Lκ_iX [right arrow over X]$_i$)X [tilde over X]$_i$= 0 with det unordered set: Lκ_1X [right arrow over X]$_1$, Lκ_2X [right arrow over X]$_2$ = 0. The problem is solved and numerically analyzed for a specific medium describable by the Treloar potential and consisting of m = 2 layers. Such a stability analysis can be extended to buckling of shallow multilayer cylindrical and spherical shells under omnilateral compression. Figures 4; tables 1; references 16.

Thermally Stressed State of Orthotropic Multilayer Plates

927F0013B Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 27 No 8, Aug 91 pp 43-49

[Article by N.D. Pankratova and A.A. Mukoyed, Institute of Mechanics, UkSSR Academy of Sciences, Kiev]

UDC 539.3

[Abstract] A plate consisting of layers with an arbitrarily variable elasticity and with an anisotropy of properties across their thickness is considered in a temperature field which puts such a plate in a state of stress and strain. For a determination of this state, it is described in accordance with the three-dimensional theories of elasticity and heat conduction for a multilayer plate in a Cartesian system of coordinates. The two systems of equations are then solved, by simultaneous integration, for a plate consisting of N layers occupying the region $z_{i-1} \le z \le z_i$, $0 \le x \le a$, $0 \le y \le b$, where i = 1,2,...,N. Contiguous layers are assumed to make close contact and their behavior to be compatible in terms of equal displacement vector u and stress tensor σ,τ components over the entire boundary between them. The temperature field in each layer is calculated by solving the equation of heat conduction $K_x{}^i\delta^2T^i\ \delta x^2 + K_y{}^i\delta^2T^i\ \delta y^2 + K_z{}^i\delta^2T^i\ \delta z^2 = 0$ ($K_{x,y,z}{}^i$ - coefficients of thermal conductivity) for boundary conditions of rigid mechanical contact and ideal thermal contact between layers, with either ideally insulating surfaces $z = z_0$ and $z = z_N$ or convective heat transfer to the ambient medium from these surfaces. For thermal stresses in the plate, there is obtained a system of equations $\delta\bar{\sigma}^i\ \delta z = B_1{}^i\bar{\sigma}^i + B_2{}^i\delta\bar{\sigma}^i\ \delta x + B_3{}^i\delta\bar{\sigma}^i\ \xi + B_4{}^i\delta^2\bar{\sigma}^i\ \delta x \times \delta y + B_5{}^i\delta^2\bar{\sigma}^i\ \delta x^2 + B_6{}^i\delta^2\bar{\sigma}^i\ \delta y^2$ ($\bar{\sigma}^i$= unordered set: $\sigma_z{}^i$, $\tau_{xy}{}^i$, $\tau_{yz}{}^i$, $u_z{}^i$, $u_x{}^i$, $u_y{}^i$, T^i, T'^i, where $T'^i = k_z{}^i\delta T^i\ \delta z$). The solution is sought in the form of a double series, for the specific case of a plate on free supports. The method can be extended to plates with nonideal thermal contact between contiguous layers. As an example is considered a plate consisting of three layers, an inner filler layer of an isotropic material (Young's modulus $E = 100E_0$, Poisson's ratio $\nu = 0.3$, coefficients of thermal conductivity $k_{x,y,z} = 500k_0$, coefficients of linear thermal expansion $\alpha_{x,y,z} = 25\alpha_0$) and outer sheath layers of a transversely isotropic material (Young's moduli $E_x = 50E_0$, $E_{y,z} = 20E_0$; Poisson's ratios $\nu_{xy,xz} = 1/10$, $\nu_{yz} = 2/3$; coefficients of thermal conductivity $k_{x,y} = 2k_0$, $k_z = k_0$; coefficients of linear thermal expansion $\alpha_x = 20\alpha_0$, $\alpha_{y,z} = 5\alpha_0$). Subscript 0 refers to the values of these parameters at ambient temperature T_0. Figures 4; tables 3; references 7.

Stressed and Strained State of Triple-Layer Shell of Revolution With Light-Weight Filler

927F0013C Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 27 No 8, Aug 91 pp 74-80

[Article by A.T. Vasilenko and I.V. Polubinskaya, Institute of Mechanics, UkSSR Academy of Sciences, Kiev]

UDC 539.3

[Abstract] A method of calculating the stressed and strained state of triple-layer shells of revolution with a compressible light-weight filler layer between two rigid carrier layers is proposed, assuming that the hypothesis of nondeformable lines normal to the surface applies to both carrier layers. The resolvent system of equations is formulated by applying the theory of thin shells to the two carriers and the three-dimensional theory of elasticity to the filler, then assuming a compatible behavior

of contiguous layers. The median surface of each carrier is referred to its own orthogonal curvilinear system of coordinates s_i, θ, γ_i (s - coordinate along the generatrix, θ - central angle in parallel circular cross-sections, γ - coordinate across the thickness read from a straight element normal to the s, θ surface; i = 1 refers to both outer carrier layers, i = 2 refers to inner filler layer). The problem is tackled by expansion of all pertinent functions including the load function into Fourier series with respect to the θ-coordinate, assuming the shell to be a circumferentially closed one. This leads to a system of ordinary differential equations with appropriate boundary conditions for the stressed state of each carrier layer, this system of equations involving: meridional force N_{si}, shear force Q_{si}, twisting force S_i, bending moment M_{si}, meridional displacement u_i, circumferential displacement v_i, deflection w_i, and angle of rotation θ_{si} of the normal line. For their state of stress and strain is then obtained an eighteenth-order system of ordinary differential equations $d\bar{y}/ds = A(s)\bar{y} + \bar{q}(s)$ ($s_0 \le s \le s_N$) with boundary conditions $B_0\bar{y} = \bar{b}_0$ at $s = s_0$ and $B_N\bar{y} = \bar{b}_N$ at $s = s_N$ (A an 18x18 matrix, B_0 and B_N 9x18 matrices, $\bar{q}$ an 18-dimensional vector, b_0 and b_N 9-dimensional vectors). The boundary-value problem for this system of equations is solved numerically by the method of discrete orthogonalization, which ensures high accuracy. For illustration, the problem has been solved by this method for a simple truncated spherical triple-layer shell, each layer made of an isotropic material and both carrier layers having the same thickness. The results have been compared with those based on the three-dimensional formulation of the problem for anisotropic shells and the agreement found to be quite close for thick shells over a wide range of the ratio of Young's moduli $d = E_{carr}/E_{fill}$ (from d = 1000 to d = 100). The problem has then been also solved for a compound shell consisting of a spherical segment (hemispherical as a special case) and a conical one smoothly joined together. Figures 3; tables 2; references 8.

Solution of Problem Regarding Initial Supercritical Behavior of Cylindrical Shells Stiffened by Stringers

927F0013D Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 27 No 8, Aug 91 pp 81-88

[Article by N.P. Semenyuk and N.B. Zhukova, Institute of Mechanics, UkSSR Academy of Sciences, Kiev]

UDC 539.3

[Abstract] The initial supercritical postbuckling behavior of stiffened cylindrical shells is analyzed, with a single parametric representation of all possible buckling modes. A shell is considered which consists of orthotropic monolayers (the axes of orthotropy not necessarily coinciding with the axes of shell coordinates) and has been stiffened by discrete stringers only. Its state of stress and strain is described in accordance with a nonlinear Timoshenko-type theory, assuming that during deformation of the structure lines normal to the reference surface rotates without breaking anywhere within the shell and stringer thickness. The variational principle of virtual displacements, based on the conditions of contact between shell and stringers, is expressed in the form of a zero sum of three double integrals. The equations of elasticity according to Hooke's law are formulated in terms of generalized forces and moments, with the curvature increments and the twist as well as the strain tensor components ε_{ij} expressed in terms of displacements. All these equations are converted to a dimensionless form by normalization of variables and used together for solving the problem of initial supercritical deformation under loads proportional to a parameter $\lambda = \lambda_c(1 + \xi a + \xi^2 b + ...)$, with the amplitude of normal deflection during bifurcated buckling as a small parameter. From these equations are then derived two systems of five differential equations, first one for calculating the critical loads by solving the appropriate homogeneous boundary-value problem (i = 1) and then one for calculating the initial supercritical strain by solving a second boundary-value problem (i = 2). The forces $t_{mn}{}^i$ and the moments $m_{mn}{}^i$ are determined from the equations of elasticity, after the expressions for the strain components have been linearized and the displacements u, v, w, θ, ψ have been replaced with u_i, v_i, w_i, θ_i, ψ_i (i = 1,2) respectively. The stability problem is solved by expanding the displacements into harmonics and retaining only the principal ones, such an approximation being sufficiently accurate for shells with discrete stiffeners. The results indicate that, regardless of the form of stability loss, local buckling of such shells leads to deflection of the stringers and that the slope of the initial segment of the supercritical trajectory segment as well as the sensitivity of the shell to imperfections will then largely depend on the transverse shear modulus of the stringers. Figures 3; tables 1; references 9.

Nonclassical Analysis of Transient Processes During Deformation of Discretely Stiffened Plates and Shells

927F0013E Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 27 No 8, Aug 91 pp 88-94

[Article by P.Z. Lugovoy and V.F. Meysh, Institute of Geophysics, UkSSR Academy of Sciences, Kiev]

UDC 539.3:534.1

[Abstract] The transient behavior of shells of rotation discretely stiffened by an array of stringers and an array of hoops is analyzed in accordance with Timoshenko's linear theory of thin shells and curvilinear beams, this being a nonclassical approach to the problem (E.I. Grigolyuk and I.T. Selezov, "Nonclassical Theories of Vibration of Beams, Plates, and Shells", ITOGI NAUKI I TEKHNIKI: MEKHANIKA TVERDYKH DEFORMIRUYEMYKH TEL Vol 5, Moscow 1973;

All-Union Institute of Scientific and Technical Information). The locations of points on the median surface of such a shell are defined by curvilinear orthogonal coordinates α_1,α_2, the two arrays of stiffeners being oriented in the corresponding two orthogonal directions. The stressed state of the shell is described in terms of the generalized displacement vector $U = (u,v,w,\varphi_1, \varphi_2)$. The strained state of each stiffener is described in terms of kinematic parameters characterizing the displacements of its cross-sections (indices referring to i-th of m stiffeners running in the α_1-direction and to j-th of n stiffeners running in the $\alpha_{\text{-direction}}$): linear displacements of their centers of gravity $u_{i,j},v_{i,j},w_{i,j}$; angular displacements about their centers of gravity $\varphi_{1i,1j}$ (rotation) and $\varphi_{ti,tj}$ (twist). The relations between displacements of the shell and of the stiffeners are established under the assumption of rigid joints. The equations of motion are then derived from the Hamilton-Ostrogradskiy variational principle of steadiness, with appropriate representation of both total potential energy and total kinetic energy of the structure. This is done by variation of the original energy functional, taking into account the force-strain-displacement relations for the shell and for each stiffener together with the conditions of contact expressed in integral form. This leads to a system of five equations of motion for a shell of rotation with discrete stiffeners, including boundary conditions for the forces (in the case of a closed shell boundary conditions at the free edge parallel to an axis of coordinates) and zero initial conditions. This system of equations, after having been approximated to second-order accuracy, is numerically integrated and interpolated by the method of finite differences according to a scheme of first-order precision with respect to the space coordinates and second-order precision with respect to the time coordinate. The method was used for evaluating the dynamic behavior of a cylindrical shell with stiffening hoops after action of an axisymmetric impact load $P(t) = A \sin(\pi t/T)$ acting during time $t \leq T$, $P(t) = 0$ at time $t > T$, which had been applied to the free edge. Figures 1; references 8.

Dynamics of Rotor Running in Two Radial Thrust Bearings and Choice of Preload

927F0011C Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 318 No 5, 21 Jun 91 pp 1120-1124

[Article by A.S. Kelzon and A.S. Meller, Leningrad Higher School of Marine Engineering imeni S.O. Makarov]

UDC 52-64

[Abstract] A rigid rotor running at a constant angular velocity ω on two thrust bearings 1,2 is considered, this rotor having a mass M, an axial moment of inertia A, and equatorial moments of inertia B. The distance $L = O_1O_2$ between the bearings is fixed and the center of rotor mass is equidistant from them. When this rotor is statically unbalanced, at rest, its center of gravity lies at a distance e below the bearing axis. A stationary system of rectangular coordinates O'xyz is selected for an analysis of the rotor dynamics: its origin O' at the center of the bearing axis (axis of rotation), x-axis coinciding with the bearing axis, z-axis transverse in the horizontal plane, y-axis vertical. For specificity are selected No 36204 bearings, whose radial stiffness in terms of change of contact angle is characterized by a reaction force $P(r) = 49(0.175 + 1000r)$ unordered set: $4.24/[8.6(5 - 1{,}000{,}000r) - (5- 1{,}000{,}000r]^{1/2}] - 1 + 2.88F_0$ (r- absolute displacement of rotor shaft in a bearing, P- force of bearing reaction, F_0- force of axial preload, all in meter-and-newton system of units) and $P(r) = kr^{3/2}$ ($k \approx 0.6\text{x}10^{10}$ N/m$^{3/2}$) according to Hertz's law. The bearing reaction is calculated by differentiating the expression for the potential energy of a deformed bearing with respect to the two horizontal coordinates x, z. Motion of a not only statically but also dynamically unbalanced rotor in linear bearings with friction is described by a system of four differential equations. Two of them include the terms $ML(d^2y_1/dt^2 + d^2y_2/dt^2)/2$ and $ML(d^2z_1/dt^2 + d^2z_2/dt^2)$ respectively. The other two equations include the terms $A\omega(dy_2/dt - dy_1/dt) - B(d^2z_2/dt^2 - d^2 z_1/dt^2)$ and $A\omega(dz_2/dt - dz_1/dt) - B(d^2y_2/dt^2 - d^2y_1/dt^2)$ respectively. The solution is sought in the form of precession at the angular velocity ω, generally $y_{1,2} = S_{1,2}\cos \omega t + \varphi_{1,2}$ and $z_{1,2} = S_{1,2}\sin \omega t + \varphi_{1,2}$. It is found by reduction of this system of equations to a system of two numerically solvable algebraic ones: $-M\omega^2(S_1 + S_2)/2 + f(|S_1|)\text{sign}(S_1 + f(|S_2|)\text{sign}(S_2 = 0$ and $(A-B)\omega^2S_1 + L^2f(|S_1|)\text{sign}(S_1)/2 = (A-B)\omega^2 + L^2f(|S_2|)\text{sign}(S_2)/2$. Under the same conditions there may exist several solutions corresponding each to a different precession mode. In the special case of a rotor balanced statically ($e = 0$) but not dynamically one of the solutions to the correspondingly simplified system of equations is cylindrical precession when $S_1 = S_2 = S$ and $M\omega^2S/2 = f(|S|)\text{sign}(S)$, the number of solutions to this equation then depending on the magnitude of $M\omega^2/2$ but always including a trivial one. When $M\omega^2/2$ is small, there exists only one other solution besides the trivial one and the rotor displacement is due to deformation of balls and races in accordance with Hertz's law. When $M\omega^2/2$ is large, there also exists only one other solution besides the trivial one and the rotor displacement is due to change of contact angle in a bearing as well as to deformation of balls and races. With $M\omega^2/2$ within the intermediate range, there are three solutions corresponding each to cylindrical precession with a different amplitude. The precession amplitude is not necessarily the largest when $S_1 = S_2$. The amplitude of rotor vibration meanwhile decreases as the axial preload force on the bearings F_0 is increased, up to a magnitude above which it ceases to influence the rotor behavior and deformations in the bearings become the sole influencing factor. So as to minimize rotor vibrations, therefore, the axial preload force should ensure that $f(r) \geq r\omega^2 \max [M/2, (B-A)/L^2]$. The article was presented by Academician N.S. Solomenko on 5 March 1991. Figures 4; references 4.

Reradiation of Sound by Solid Bodies of Various Shapes

927F0011B Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 318 No 5, 21 Jun 91 pp 1117-1119

[Article by G.M. Degtyarev and A.G. Ivanov-Rostovtsev]

UDC 621.793

[Abstract] Scattering of sound by elastic solid bodies is analyzed from the standpoint of their effectiveness of sound reradiators. The analysis, based on experimental data, takes into account the geometry as well as the physical properties of such sound scatterers. A thin rod was suspended horizontally in water filling an 8 m high tank with a 1.5x2 m^2 cross-section and excited by sound pulses carrying tone-frequency waves. At some distance from the rod a recording instrument plotted its response in the form of its backscattering indicatrix. Rods of eight different materials (steel, aluminum, copper, brass, tin, graphite, ebonite, thermoplastic) were used for the experiment, rods L = 1.5-10 cm long and D = 0.1-1 cm in diameter of each material. The frequency f of the incident sound signal was varied for each rod: 30 kHz, 50 kHz, and 200 kHz. A comprehensive empirical analysis of the data is facilitated by generalizing the wave parameter defined as $kA = 2\pi f(DL)^{1/2}/c_L$ (k- wave number, c_L- speed of longitudinal waves) so as to characterize the correlation between signal frequency, rod elasticity, and rod geometry. For comparison and considering the analogy between elastic waves in thin rods and in plates, a similar experiment was performed with circular thin steel disks L = 0.05-0.6 cm thick and D = 1.5-5 cm in diameter. These disks, suspended vertically, were also excited by 30 kHz, 50 kHz, and 200 kHz sound signals. Their scattering indicatrices revealed maximum values corresponding to reradiation of the zero mode of antisymmetric flexural vibrations. A comparison of the reradiation patterns of rods and disks reveals two transition zones between intrinsic rod→ sphere and plate→sphere asymptotes, which need to be considered in theoretical solution of sound scattering problems. It also reveals a symmetry of reradiation by rods and disks relative to reradiation by spheres, namely analogous backscattering indicatrices of a rod and disk with equal length-to-radius and radius-to-thickness ratios respectively when both have been excited by sound signals of the same frequency. The sound reradiation region, plotted in length-frequency and diameter-frequency planes in log-log coordinates log(L/A) and log(D/A) versus log(f/N) ($N = c/2\pi(DL)^{1/2}$) is found to be bounded by the same outer square for all rods and disks but by different inner squares depending on their characteristic geometrical ratio, the inner boundary for a sphere shrinking to a point at the center (origin of coordinates). The results of this analysis indicate that an elastic sphere is an ineffective sound reradiator, its geometry being balanced or perfect (characterized by one dimension only) and invariant. Elastic thin rods and thin disks forms are, from the standpoint of sound reradiation, unbalanced and imperfect relative to a sphere (their geometry being characterized by two dimensions). The article was presented by Academician N.S. Solomenko on 28 December 1990. Figures 2; references 3.

Stress Singularity in Vicinity of Vertex of Elastic Trihedron

927F0011A Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 318 No 5, 21 Jun 91 pp 1113-1116

[Article by V.A. Babeshko, corresponding member, USSR Academy of Sciences, Ye.V. Glushkov, N.V. Glushkova, and O.N. Lapina, Kuba State University, Krasnodar]

UDC 621.793

[Abstract] Stresses at the contact between an elastic trihedral pyramidal punch and an elastic medium occupying one half-space are analyzed for singularity in the vicinity of the indenter vertex as the pyramid becomes a half-cube. The analysis is performed by reduction of the problem to a system of integral boundary-value equations and a Mellin transformation of the latter, the resulting one-dimensional integral equations then being discretized by expansion of their solution into a series of orthogonal polynomials which include weight factors accounting for singularities at the punch edges. A trihedral pyramid is considered with given displacements v on one face and given stresses t_1, t_2 on the other two. Each face Γ_m (m = 1,2,3) is referred to three three-dimensional systems of coordinates: rectangular (x_m, y_m, z_m), cylindrical ones (r_m, φ_m, z_m), and spherical (R, x_m, χ_m). The vertex angle of each face is $\alpha_m > 0$ and the dihedral angle between each face m and its neighbor n is $\pi + \theta_m$ ($\theta_m < 0$). With q^m = unordered set:$\tau_{rz}{}^m$, $\tau_{\varphi z}{}^m$, $\sigma_z{}^m$ denoting the sought unknown stresses on face m, displacements u^{nm} and stresses p^{nm} inside the elastic medium in the plane coinciding with one of the two other faces n under those unknown stresses q^m are, with the aid of Green's matrix for an elastic half-space, expressed through integral operators for those unknown stresses q^m. Satisfying the boundary conditions at each face $\Sigma_{m-1}{}^3 u^{1m} = v$ (x on face Γ_1) and $\Sigma_{m-1}{}^3 p^{nm} = t^n$ (x on face Γ_n, n = 2,3) then leads to a system of integral boundary-value equations which can be solved for those unknown stresses q^m. The method is demonstrated in the case of cubic trihedral with the vertex angle of one face α_1 $\pi/2$ const and the dihedral angles $\varphi_1 = \varphi_3 = -\varphi$ varied from 0 (pyramid degenerated into an elastic half-space in contact with a punch occupying a quarter-space) to $\varphi = \pi/2$ (cubic trihedral). The solution is shown to converge much faster than the solution sought by applying the method of finite or boundary elements, an effective one for wedges, to polyhedra such as pyramids. Figures 1; references 11.

Status and Prospects for Development of Robotics in USSR

927F0029A Moscow MEKHANIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA in Russian No 7, Jul 91 pp 1-3

[Article by V.P. Stepanov, candidate of technical sciences, V.B. Velikovich, engineer, and B.M. Kozunko, candidate of technical sciences, under the "General Problems of Robotics" rubric: "Status and Prospects for Development of Robotics in Country"]

UDC 621.965.8

[Text] Accelerating scientific-technical progress is tied to concentrating efforts in the priority directions of developing the national economy.

One of these directions is robotics. In previous five-year-plans it developed essentially within the framework of branch programs. This led to duplication of developments and creation of numerous small-capacity production processes (in 1987, for example, 180 models of industrial robots were produced at 142 plants under 18 ministries).

In the period from 1972 to 1985, 280 models of industrial robots intended for different technological purposes were created in the field of robotics in the USSR. More than 100 of them were put into series production. Series-produced robots were used as the basis for creating about 100 types of robotic manufacturing systems.

Before 1985, the yearly output of industrial robots in the USSR increased annually and reached 15,400 units per year. In subsequent years, the manufacture of industrial robots began to decrease. Only 4,593 units were manufactured in 1989.

This decrease in the manufacture of industrial robots in the USSR was due to a sharp reduction in demand from user-enterprises under the conditions of an emerging market.

Any critical assessment of the level of development of domestic robotics must acknowledge its lag behind current progress in the developed countries. The initial period of the development of robotics in the USSR was one of mass creation of new designs without developing them to world market requirements. In fact, not one industrial robot design was refined to the required level.

The main obstacle in creating modern industrial robot designs was and continues to remain the lagging infrastructure and, above all, the market of components intended for general machine building use: hydraulic, pneumatic, electrical, and electronic sensors; all drives in general; and automated control systems.

The miscalculations in the sphere of installing industrial robots, which in past years was done primarily by directive, have been significant. This fact, together with the inadequate quality (above all, operating reliability) of the robots and their high cost in relation to the wages of workers servicing industrial robots, has caused many users to develop a negative attitude toward them.

The Robot Interbranch Scientific-Technical Complex, which was organized in accordance with a 1985 USSR Council of Ministers decree, should play a decisive role in increasing the efficiency of robotics in the situation that has evolved.

The goal of creating an interbranch complex is to concentrate scientific efforts and material and technical resources on the problems of robotics, to emerge to one of the leading positions in world robotics, and to reduce the time required to create and introduce products.

The main tasks are as follows: implement a unified engineering policy; conduct scientific research and experimental design work; manufacture prototype industrial robots and the products required to complete them; and determine the prospects regarding their development (i.e., available financial, labor, and material resources and the amounts of capital investments, personnel training and retraining, and industrial robot service and repair that will be required).

Yearly plans for the years 1987 through 1990 corresponding to the store of scientific-technical know-how in the field of robotics were compiled in accordance with the tasks that have been formulated and based on the concept of the development of this priority direction that has been developed by the Robot Interbranch Scientific-Technical Complex. These plans were formulated so that beginning in 1990-1991, robots characterized by a high engineering level and capable of competing on the world market could be manufactured and introduced into industry on a wide scale.

In accordance with the unified plans for the complex's operation, 25 prototype industrial robots were created in the previous period (the Robot Interbranch Scientific-Technical Complex had only planned for the production of 19 prototypes per five-year-plan). Five models of industrial robots and 18 robot components were launched into series production. They included several type sizes of linear and matrix TV cameras for robot vision systems that are in no way inferior to their world analogues. Especially noteworthy among the robots recommended for series production were those of the Start-rekuper and Krab-rekuper lines. These robots use the principle of energy recuperation, which entails outfitting the robot's drive with an elastic energy accumulator (flat spring) that accumulates the excess energy in each preceding cycle and releases it in each subsequent cycle. This accumulator was developed at the State Scientific Research Institute of Machine Science imeni A.A. Blagonravov and was manufactured by the Forging Robots Planning, Design, and Technology Institute. Industrial robots with energy recuperation make it possible to reduce the specific amount of metal required for a design by a factor of 2 to 3, reduce its energy requirement by a factor of 5 to 8, and increase its speed by a factor of 2 to

3. The labor intensity and cost of manufacturing robots also drop sharply. These robots are without analogues in foreign robotics. The total demand for industrial robots of this type will, according to experts, soon range from 25,000 to 30,000 units. The savings for this entire volume produced will be between 75 and 100 million rubles with a cost recuperation period of 2 to 3 years. The robots were presented at the exhibit Avtomatizatsiya-89 in Brno (Czech and Slovak Federated Republic), where they received a high evaluation.

By using work related to dynamic coupling, the Tekhnopribor Scientific Production Association (Smolensk) and the Robot Interbranch Scientific-Technical Complex collaborated with the State Scientific Research Institute of Machine Science imeni A.A. Blagonravov to perfect the model TUR-2.5K and TUR-10KM robots so as to increase their speed by a factor of 1.5.

A number of organizations set up production of licensed models of industrial robots.

By license of the German firm Kuka, the AvtoVAZ began production of model PR161/61 industrial robots for spot resistance welding. More than 500 industrial robots were manufactured in 1986-1990. The main users of these industrial robots are automotive industry enterprises, including the Moscow Automotive Plane imeni Lenin Komsomol [AZLK], Zaporozhye Automotive Plant Kommunar [ZAZ], Volzhsk Automotive Plant imeni 50th Anniversary of the USSR [VAZ], and Moscow Automotive Plant imeni I.A. Likhachev [ZIL] (about 50 to 60 units are used at each enterprise).

By license of the English firm G-V, the Scientific Production Association imeni Frunze has set up production of the Komparm-Sumy industrial robot for use in painting operations. Robotic manufacturing systems have been created on its basis.

As a way of further developing the decree, the USSR State Committee for Science and Technology formulated and approved a unified five-year-plan.

In accordance with this plan, the robotics section was to develop 19 models of industrial robots. This did not include industrial robots developed by the enterprises of the machine building sectors.

The list of industrial robots for the five-year-plan included the development of an array of industrial robots: industrial robots with energy recuperation and with load-lifting capacities of 1.25, 2.5, 5, and 10 kg; gantry-type industrial robots with load-lifting capacities of 10, 20, 40, and 160 kg; traveling-type robots with load-lifting capacities of 160 and 320 kg; and floor-model robots with load-lifting capacities of 2.5, 10, and 20 kg. These robots were created by the Experimental Scientific Research Institute of Metal-Cutting Tools [ENIMS], the Tekhnopribor Scientific Production Association, and the Krasnyy Proletariy SPO.

It should be said that the five-year-plan was compiled in a hurry and that there was virtually no direction when the more detailed unified yearly plans were developed.

Without going into the details of the unified yearly plans of the Robot Interbranch Scientific-Technical Complex, we will note the most important developments with respect to the section on robotics. The plan called for the creation of special industrial robots of the Kaskad system (reprogrammable manipulation systems with a pneumatic drive for assembly operations and capable of lifting up to 6 kg). The plan also called for creation of the following robots: robots with energy recuperation for sheet-stamping production processes that are capable of lifting 1.25, 2.5, 5, and 10 kg; robots for hot die forging with the capability of lifting 10 and 40 kg; a robocar with load-lifting capacities of 500 and 1,000 kg; traveling transport industrial robots with load-lifting capacities of 500, 1,000, and 10,000 kg; robots for automatic thermoplastic machines with a load-lifting capacity of 5 kg for painting operations (the model Komparm-Sumy); robots for arc and resistance welding; robots for biophysical operations (the REM-6); and industrial robots capable of moving along vertical surfaces for special work (extinguishing fires, cutting, painting, etc.).

The plan also called for the following universal industrial robots: gantry-traveling robots with load-lifting capacities of 20, 40, and 160 kg created by the Ukrainian Scientific Research Institute of Machine Tools, Tools, and Instruments and the Experimental Scientific Research Institute of Metal-Cutting Tools; floor-model robots with load-lifting capacities of 2.5, 10, 20, and 40 kg created by the Tekhnopribor Scientific Production Association, the Experimental Scientific Research Institute of Metal-Cutting Tools, and the Krasnyy Proletariy SPO; and floor-model robots with load-lifting capacities of 15, 63, and 80 kg created by the AvtoVAZ.

About 25 basic models of different types of industrial robots were created. With respect to the all-union type classification of industrial robots for 1986-1990, these robots will replace no fewer than 70 models of industrial robots created in eight sectors of the national economy.

Also noteworthy is the work of enterprises in the defense sectors, which have created a number of universal industrial robots. Specifically, they have created the following: the models Granat-2.5 and Granat-10, which have electromechanical drives and a numeric performance evaluation and review technique [SPU or PERT]; the model Granat-10BK robot, which has an electromechanical drive, uses a numeric PERT, and is capable of lifting 15 kg; a position-type microrobot with an electromechanical drive and a numeric PERT that is capable of lifting 0.5 kg; robots for arc welding base members weighing up to 1,000 kg (the model SUR-25) and for welding long, flat structures; and a robot similar to the Reis model (Germany) with an anthropomorphic arm capable of moving in a vertical plane (the model U-15).

Of the aforementioned assignments, two were completed to the point of launching the industrial robot into series production (the models Granat-2.5, Granat-10, and SUR-25).

It has now become obvious that engineering policy in the field of robotics must be corrected to allow for the fact that an increase in the demand for industrial robots and flexible automation equipment will occur in several years, when the disproportions between work force and equipment costs are overcome.

The world engineering development of industrial robots is proceeding in two directions: execution of equipment loading and unloading operations and execution of basic manufacturing operations (assembly, welding, etc.).

Most of the industrial robot park in the USSR is intended for use in executing auxiliary operations (mainly loading and unloading basic manufacturing equipment). This state of affairs is explained by the fact that the head organizations with respect to robotics in the different sectors are concerned above all with robotizing machining processes and by the fact that new trends in the development of robotics were not assessed in a timely manner.

A comparative analysis of the industrial robot park in the USSR and in industrially developed countries revealed that from the standpoint of production volumes (and consequently the industrial robot park), the USSR is at the forefront. From the standpoint of the distribution of robots throughout different manufacturing processes, however, our industrial robot type size classification is very different from those of Japan, the United States, Germany, Italy, etc. This discrepancy is expressed in the low relative amount of industrial robot models used to perform basic manufacturing operations (welding, painting, assembly, etc.). The USSR has created an array of industrial robots to service basic manufacturing equipment (metal-cutting machines, press-forging and casting equipment, equipment to automate loading and unloading on conveyers). With respect to work to create robots for welding, painting, and applying adhesive coatings and sealants, however, the USSR is still in the prototype stage.

The main directions of engineering policy in the sphere of robotics should be as follows:

—reject the notion of developing industrial robot type classifications based on frozen ideas regarding the need for them to set up the manufacture of type size models in large series and switch instead to the natural formulation of market demand;

—develop an orientation toward manufacturing industrial robots on an individual order basis but continue to manufacture modular-unit manipulator subassemblies in series.

The modular design principle based on using computer-aided design [CAD] systems to quickly develop (synthesize) industrial robot designs to meet the needs of a specific client appears to be most promising in this respect.

Also needed is the parallel development of an infrastructure of means to design automated systems in different types of manufacturing processes, including equipment accessories and software geared toward the specific application of industrial robots (in welding, laser treatment, painting, etc.), peripherals (stroke tables, positioners, and tray loaders), and sensors (ultrasound and infrared locators, robot vision systems, etc.).

Cooperation with foreign firms in the areas of using components, purchasing manufacturing licenses, and (at the same time) selling our competitive developments abroad as partners is also needed.

We must move from a strategy of eliminating our lag in all directions of robotics to a strategy of concentrating our efforts on those research, design, and manufacturing directions in which we now have competitive developments.

Numerical Controllers for Industrial Robots. Status and Prospects

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[Article by I.B. Knauer, candidate of technical sciences]

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[Text] At the current level of development of robotics controllers are becoming decisive in the creation of promising new models of robots with extensive functional capabilities with respect to automating different manufacturing processes including assembly, arc and resistance welding, painting, etc.

The Robot Interbranch Scientific-Technical Complex has developed a program to create modern industrial robot controllers. The program presumes the creation of an integrated control system synthesized from standardized functional components: robot controllers, the transport-and-storage and auxiliary equipment that is part of a robotic manufacturing system, controllers intended for different purposes, standard PC-based program preparation methods, self-contained positioners, controlled drives, and position and adaptation sensors.

The specified functional elements may be combined into a local system of the necessary configuration by using compatible interfaces and protocols. Accomplishing this task requires meeting a number of requirements

regarding the design, component base, and interfaces linking the functional modules.

The following distinctive features are characteristic of modern industrial robot controllers:

—modular design and software of the controllers with respect to the number of controlled axes and I/O instructions and the number of external interfaces with standard equipment, computers, sensors, and the local area network;

—high computer speed (1.0 to 1.5 million operations per second) and increased memory (up to 296 kbyte, including up to 64 kbyte to write and store user programs);

—multiprocessor structure of all computer equipment thanks to the use of a single type of processors based on the Intel microprocessor family (16- and 32-bit) and a unified system bus (MULTIBUS);

—openness and flexibility of the devices' software, which simplifies the methods users employ for external programming and communication with the system;

—standardization of intrasystem and external interfaces of the control systems, design components, software, and programming languages, thus making the hardware and software compatible with the top control levels, standard equipment, and other functional modules;

—development of hardware-software diagnostic modules, computer-aided design [CAD] modules automating control program preparation, adaptation modules based on robot vision and touch, and servo and self-contained electric drive modules based on thyratron gearless electric motors;

—trend toward the use of PC's as control system components.

Most modern foreign control systems meet the specified requirements. Included among these systems are developments of the firm Siemens (Germany), which is represented on the world market by the Simatik distributed system. It includes the Sinumerik and Sirotek controller modules, Simodrive electric drives, Simatik controllers, and standard equipment and adaptation modules.

The functional modules of the Simatik system have standardized internal and external interfaces and may be connected to a local area network (by a Sinek bus). Analogous systems exist in the Czech and Slovak Federated Republic (the Kirs system) and in the Republic of Hungary (the Mikromatik system).

The program of operations of the Robot Interbranch Scientific-Technical Complex calls for the creation of an analogous distributed system in 1991-1995. A number of prototype functional modules have been developed, including an industrial robot control device, controllers, electric drives, position and touch sensors, and a local area network interface. The model 4S basic position-loop industrial robot controller was developed in 1989-1990 (the Elektronmash Scientific Production Association in Leningrad was the head developer and manufacturer). The model 4S300R hardware-software modification was developed to control the model MA160K traveling industrial robot (Experimental Scientific Research Institute of Metal-Cutting Machines Scientific Production Association), the model M20K95.01 floor-model industrial robot (Krasnyy Proletariy MSPL [not further identified]), and the model UR-15 industrial robot (Riga Robot Plant). The development of the model 4S300R prototype system to control model M20K85.01 industrial robots is planned for 1991.

The model 4S device is distinguished by the "flexibility" of the software-hardware that has been included in it to expand its functional capabilities with respect to user requirements.

The device's architecture makes it possible to vary computing and control capacity without any structural changes. This is accomplished by configuring a specified number of microprocessor modules and using faster processors. The hardware-software configuration contains more than 50 hardware and 1,000 software modules. External standard interfaces make it possible to connect the device to standard equipment, higher-level computers, and a local area network bus. The following are the main technical parameters of the model 4S base device.

Technical Characteristics of the Model 4S Base Device

Control class	position-loop
No. controlled coordinates:	
maximum	8
with shaping	6
including positioning	2
Main method control program preparation:	
training	+
analytical	+
from higher-level computer	+
Standard equipment for service and control program preparation:	
alphanumeric display	+
graphic display	+
external program carrier	floppy disk storage
control and training panel	+
operator panel	+
No. and parameters of I/O:	
maximum	256/128
in one module	40/24; level +24 V
No. and parameters of analog input signals	8, +/- 10 V
No. and parameters of input signals to control servo coordinate drive	8, level +/-10 V; load not to exceed 20 mA per channel

Technical Characteristics of the Model 4S Base Device (Continued)

Control class	position-loop
No. basic control programs, not more than	9,999
subprograms, not more than	999
No. positioning points, no more than	4,000
Memory to store control programs, kbyte	up to 256 (CMOS)
No. parallel-operating processors	2
speed, million operations/s	1.0
microprocessor family type	K1810VM86
No. and type of measuring channels	8, photopulse, inductive
Overall dimensions, mm:	
instrument version	343 x 463 x 265
	450 x 500 x 350
cabinet version	1,200 x 650 x 600
Power requirement, kW	0.4
No. and type of external interfaces	2 channels, IRPS [not further identified]

Thanks to its capabilities, the basic design may be used to create different hardware-software versions. The Elektronmash Scientific Production Association in Leningrad is planning to manufacture a commercial batch of model 4S200R devices in 1991. The model will be a four-coordinate modification of the base model.

The class of positional controllers is represented at the Robot Interbranch Scientific-Technical Complex by the model Sfera PS. It was developed at the Granat Scientific Production Association in 1989 to control the model MPM-40 gantry industrial robot (Minsk Pull-Broaching Machine Plant) and the model MA160K traveling industrial robot (manufactured by the Experimental Scientific Research Institute of Metal-Cutting Machines Scientific Production Association). The model Sfera PS is based on Sfera model hardware-software modules and represents a multiprocessor designed in accordance with a hierarchical principle based on the KR1801 microprocessor family. The system includes an external floppy disk storage module, a display terminal, and a manual control panel.

A printer may be connected through a parallel interface.

Technical Characteristics of the Sfera-PS

No. simultaneously and independently controlled manipulator axis drives	6
Parameters of drive control channels:	
control voltage, V	+/-10
load resistance, kΩ	2
Programming method	training, analytical
External program carrier	floppy disk storage
No. digital I/O signals	96/64
Parameters of digital signals:	
input	level, 24 V; load, 20 mA
output	level, 24 V; load, 0.2 A
No. and types of external interfaces	3, IRPS; 1, IRPR-M
No. and type of channels to connect transducer	6, model VYe178 photoelectric
Amt. of memory (RAM, volatile), kbyte:	
central processor	64
drive controller	4
communications processor	4
Amt. of PROM (nonvolatile with UV erasure), kbyte	32
Overall dimensions, mm	618 x 602 x 1,818
Power requirement, kW, not more than	0.8

The Robot Interbranch Scientific-Technical Complex has been developing cyclic controllers. In 1989-1990 it developed the model S171.21 controller (Mikon), which is a freely programmable controller. The device is intended for controlling different cyclic industrial robots, including models to automate hot stamping. When external interfaces are present, it may serve as the basis for decentralized control systems that may in turn include computers, numeric control systems, and service equipment.

The device has a modular design and contains basic power supply and control units plus additional modules provided at the customer's request. They include units to monitor, diagnose, and control the controlled electric drive and three instruction expander units.

Series K580 microprocessors, K573RF4 PROM microcircuits, and K537RU10 RAM microcircuits have been used as the main component base.

Commercial production of the device began in 1990.

Technical Characteristics of the S171.21 Device

Type of device	cyclic
Programming language	A-Cycle
Capability of programming logic functions executing I/O instructions	AND, OR, NOT; module summing; comparison; arithmetic operations; conditional and unconditional jumps; interrupts; time delays; event counters; link with computers; test check; information display
User program size, kbyte	2 to 8 (PROM)
Additional user program, kbyte	8 to 16 (ROM)
No. instructions in user memory, no more than	999 (PROM), 1,998 (ROM)
No. and type external interfaces	1, IRPS
No. timers/counters	296/256
Max. no. discrete I/O (with three expander units)	256/224
incl. expander unit	64/64
Digital signal parameters:	
voltage, V	level 24
output load, A	up to 0.5
input load, mA, no more than	30
No. controlled cyclic robot axes	6
simultaneously controlled	3
Output coordinate control signal parameters:	
voltage, V	level 24
current load, A, no more than	1.0
starting current, A, no more than	6.0
Max. power requirement (with instruction expander units), W, no more than	300
Overall dimensions, mm:	
Power supply unit	466 x 220 x 305
Basic control unit	466 x 220 x 457
Expander unit	466 x 220 x 310

The development of a prototype modified device that will be provided with modules to control a servo drive (up to four coordinates) is planned for 1991.

In that particular modification, the device may be recommended for positional control of manipulators.

The concept of the development of industrial robot control systems assumes that the extent to which a system is furnished with functional modules is one of the most important indicators of system quality. This applies both to those functional modules that were mentioned above and to manipulator control devices, self-contained drives, adaptation sensor modules, standard service and program preparation equipment, etc.

In 1989-1990, besides creating industrial robot controllers, the Robot Interbranch Scientific-Technical Complex also worked to develop promising self-contained drives and position transducers. Working together with the Ukrainian Scientific Research Institute of Machine Tools, Tools, and Instruments, the Experimental Scientific Research Institute of Metal-Cutting Machines Scientific Production Association developed a prototype positional drive. The device has a hierarchical, two-level structure. The top level is a master controller based on a series K1810 microprocessor that executes an algorithm for positional control of two manipulator coordinates and that provides an external interface with the higher-level computer.

The lower level of the device serves as the power converter of a variable-speed electric drive based on model DSM synchronous electric motors. The device includes a manual programming panel that performs the functions of manually controlling of the electric drive's coordinates, specifies positioning points and modes, and indicates the status of the device.

The self-contained drive configuration also includes model DSM servo motors equipped with combined winding-switching, shaft rotation speed, and shaft position sensors.

The device is distinguished by the fact that the external interface is designed to connect the device to a local area network bus to set up a distributed system to control a multicoordinate drive from the higher-level computer.

Technical Characteristics of the Self-Contained Drive

Amt. of user memory, kbyte	4
No. coordinates in module	2
Max. transducer resolution, rad, no more than	0.0025
Max. electric drive shaft rotation speed, s^{-1}, no more than	50
Discreteness of specifying movement speed, rad/s	$V_{max}/1,000$
Discreteness of specifying acceleration, rad/s^2	$W_{max}/100$
Max. amt. of programmable movement per frame, units	9,999.999
Max. amt. of programmable speed per frame, units	999.999
Max. amt. of programmable acceleration per frame, units	99.9
No. drive modules connectable to system bus, no more than	4
Bus length, m, no more than	60
No. digital I/O signals	64/32
Digital signal parameters:	
input	level, 24 V; 20 mA
output	level 24 V; 2 A
Rated moment of servo motors, N-m	GOST RYaD 0.1-10

As a further development of work in this field, a six-coordinate anthropomorphic industrial robot controller based on the specified electric drive modules is slated for 1991-1992.

The hardware-software that has already been created or else is currently being planned is making it possible to synthesize systems to control robotic manufacturing systems and universal and manufacturing robots. Further development of the distributed system described above is slated to proceed in the direction of creating adaptation software-hardware, local area network interfaces, monitoring and diagnostic equipment, and CAD applications packages for program preparation. The creation of promising PC-based controllers is also planned.

Contents of 'Mechanization and Automation of Manufacturing', Jul 1991

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